ISSN 0705-5927

Reclamation, Conservation and the Environment

Proceedings of the
13th CLRA Convention
August 7th to 10th, 1988
Ottawa, Ontario

CLRA
ACRSD

Destination 88

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

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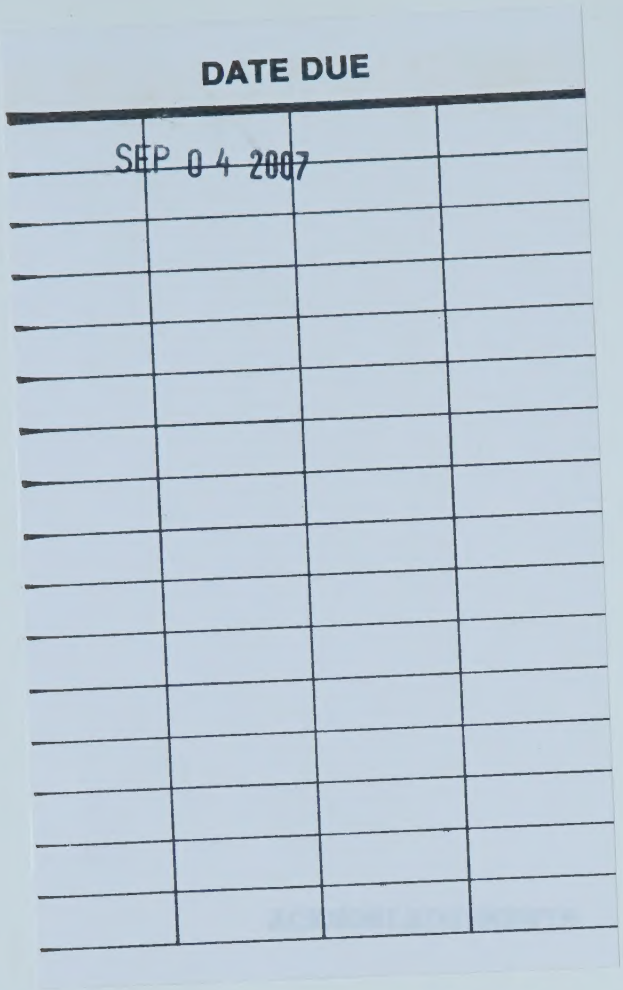

The CLRA wishes to greatfully acknowledges the contribution of the Crop Development Division, Agriculture Development Branch, Agriculture Canada and the assistance of David Murray who organized and arranged the preparation of the conference proceedings.

The assistance of M.E. Murray in proof reading the draft documents was greatly appreciated as was the help of Daniel Boivin, of the Quebec Chapter of CLRA/CRSD, in arranging for translation of abstracts.

Printing costs of the conference proceedings were paid by CANMET (Canada Centre for Mineral and Energy Technology), Mineral Sciences Laboratories of Energy, Mines and Resources Canada. This support is gratefully appreciated.

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Abstract:

Forestry dominates the economy of British Columbia. From 1976-86, approximately 1.8 million hectares of forest land were harvested. Ground-based harvesting systems, using tractor or skidders, were used on 80% of the cut over area. These systems, which can degrade 15 to 30% of a cut block, have created at least 250,000 hectares of degraded forest land. A recent problem analysis by the CFS estimates the cost of this degradation at approximately $80 million in potential timber yield annually, with a ten percent increase each subsequent year.

Ground-based timber harvesting can result in extensive soil compaction, nutrient displacement, and accelerated soil erosion. In the past, a number of regional guidelines and procedures have been instituted to minimize soil degradation and to promote rehabilitation. The results, however, have been far from satisfactory. Although well intentioned, most of the procedures lack operational effectiveness, and enforcement has been sporatic. At present, a major effort is underway to improve these guidelines and procedures using recent research and operational trials. With stronger enforcement (or penalties) and improved procedures, site degradation loss due to forest harvesting should be minimal. This paper reviews both the lessons learned from the past and the new direction currently being developed.

Résumé:

La foresterie domine l'économie de la Colombie-Britannique. De 1976 à 1986, environ 1.8 millions d'hectares de terres forestières ont été récoltées. Des systèmes de récolte au sol, utilisant des tracteurs et des débusqueuses, ont été utilisés sur 80% de la surface d'exploitation. Ces systèmes, qui peuvent dégrader de 15 à 30% de l'assiette de coupe, ont créé au moins 250 000 hectares de terres forestières dégradées. Une analyse récente du problème par la CFS estime le coût de cette dégradation à un potentiel d'environ 80 $ millions en récolte forestière annuelle, avec une augmentation de 10% chaque année subséquente.

La récolte avec une machinerie au sol peut amener une compaction du sol, la perte d'éléments nutritifs, et une érosion accélérée du sol. Par le passé, certaines lignes de conduites et modalités ont été établies afin de minimiser la dégradation du sol et de promouvoir la réhabilitation. Cependant les résultats ont été très peu satisfaisants. Quoique bien intentionnés, la plupart des procédures manque d'efficacité opérationnelle, et les mises en application se font de façon sporadique. A présent, un effort majeur est entrepris afin d'améliorer ces lignes de conduite et procédures en utilisant les essais de recherche et d'opérationnalisation les plus récents. Avec des impositions (ou des punitions) renforcées et des procédures améliorées, la dégradation des sites causée par l'exploitation forestière devra être à son minimum. Cet exposé fait donc la revue des leçons du passé et de la nouvelle voie directrice actuellement en développement.

NOTE: The CLRA Conference committee regrets that a full copy of the paper was not received in time to be included in the proceedings. For more information, we suggest you contact the author at 604-986-4186.

MANAGING SITES CONTAMINATED BY HAZARDOUS SUBSTANCES IN QUEBEC

GESTION DES LIEUX CONTAMINES PAR DES SUBSTANCES DANGEREUSES AU QUEBEC

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Abstract:

In Quebec, the management of sites contaminated by hazardous wastes or other hazardous substances has been undertaken by the provincial Ministry of Environment through two recent programs.

The first program (GERLED) addresses hazardous waste disposal sites (active or inactive) for which an inventory was made in 1983-84. The origin of some of these sites dates back to the beginning of the century. Needless to say, the management of many of these landfills is now considered inadequate and has resulted over the years in the contamination of surrounding soils and groundwater. The Ministry incites the owners to conduct hazard assessments on their sites and to implement restoration measures to diminish or eliminate threats to human health and to the environment.

The second program (GERSOL) is devoted to the management of contaminated land by hazardous substances. The ongoing modernization of the industrial structure in Québec results in the decommissioning of many old industrial sites. Some of these sites formerly located on the outskirts of cities, are now prime residential, commercial or light industry lots since cities have grown around them. Aware of the fact that some industries may have contaminated the soil and groundwater while producing or utilizing hazardous substances, the Ministry has established the Contaminated Sites Rehabilitation Policy. This Policy favors the redevelopment of such land while avoiding contamination-related hazards by providing guidelines for the necessary assessment and rehabilitation procedures.

Résumé:

Au Québec, les lieux contaminés par des substances dangereuses font l'objet d'interventions par le ministère de l'Environnement dans le cadre de deux programmes. Le premier programme (GERLED) concerne les lieux (inactifs ou actifs) d'élimination des déchets industriels qui ont été inventoriés en 1983-84. L'origine de beaucoup de ces lieux remonte à plusieurs années. Les pratiques de gestion de ces déchets à cette époque étant maintenant jugées inadéquates, le ministère incite les propriétaires de ces lieux à procéder à leur caractérisation et à leur restauration au besoin pour diminuer ou éliminer leur impact sur l'environnement.

Le second programme (GERSOL) s'inscrit dans le cadre de la Politique de réhabilitation des terrains contaminés. La modernisation de la structure industrielle au Québec amène la fermeture et le démantèlement d'installations industrielles maintenant vétustes. Les terrains de ces anciennes industries étant maintenant situées au coeur d'agglomérations urbaines, beaucoup de ces terrains sont réutilisés à des fins commerciales ou résidentielles. La Politique vise à favoriser le recyclage de ces terrains tout en s'assurant qu'ils ont préalablement été décontaminés et réhabilités de façon à ce qu'ils soient sécuritaires pour leur nouvelle vocation.

THE GERLED PROGRAM

The GERLED program (Gestion et Restauration des Lieux d'Elimination de Déchets dangereux), which started in October 1983, has the following mandates:

- To indentify and prepare a preliminary assessment of sites that were used to dispose of hazardous wastes in Québec;
- To establish action priorities based on the preliminary assessment;
- To prepare and execute a plan of action;
- To remediate any contamination-related hazard.

Carried out primarily in 1983-84, the identification of sites resulted in the publication of the **Inventory of Sites used for the Elimination of Hazardous Wastes in Québec**[1]. Given the restrictions on any such exercise, the inventory is necessarily incomplete and subject to change; new sites are to be added as they are identified. To this day, of the 1095 waste disposal sites considered, 333 have been retained in the inventory and classified in three potential hazards categories (Fig. 1): I - Extreme hazard; II - Moderate hazard; or, III - Lesser hazard. Mining wastes disposal sites in the inventory account for 32% of the total number of sites. Owners of hazardous waste disposal sites can be divided into 4 major groups (Fig. 2): most of the sites belong to private enterprises (70%) while the provincial and local governments, unaware of potential problems, have inherited over the years a sizeable number (15%) of sites.

Having carried out the greater part of the inventory and preliminary assessment work, the Ministry began, in 1985, the next phase of the GERLED program which aims ultimately to implement remedial actions on all contaminated sites. The plan of action, to attain such a goal for each site, is divided into five steps: detailed hazard assessment; choice and preparation of corrective measures; implementation of corrective measures; verification and assessment of corrective measures; and, finally, environmental follow-up.

Initially, the Ministry considers the owners as responsible for contamination emanating from a given site. The Environment Quality Act (R.S.Q., c. Q-2) and the Hazardous Wastes Regulation (Q-2, r.12.1) provide the Ministry with legal tools for the enforcement of corrective measures on hazardous waste disposal sites. However, until now, the GERLED program has been quite successful in obtaining the collaboration of many responsible owners (mostly at industry-owned sites) without having to resort to legal action.

Hazard assessment work has been undertaken on some 101 sites and remedial action feasibility studies or remedial actions have been started on 54 sites.

The overall cost of cleaning up the legacy of hazardous waste disposal sites in Québec has not been precisely evaluated. If such a comparison can be made, New-Jersey[2] estimates that the costs of cleaning such sites in the State averages $5 million U.S. per site. Using these numbers, a rough estimate of the total cost for the cleanup of all the sites in Québec would be $2 billion Cdn.

Since most of the sites still belong to private enterprises the major part of the bill should be assumed by these owners.

As the GERLED program was underway, an increasing number of landowners and developers wishing to sell or reuse former industrial sites sought the advice of the

Figure 1
CLASSIFICATION OF WASTE DISPOSAL SITES
BASED ON THE CATEGORIES OF POTENTIAL HAZARD

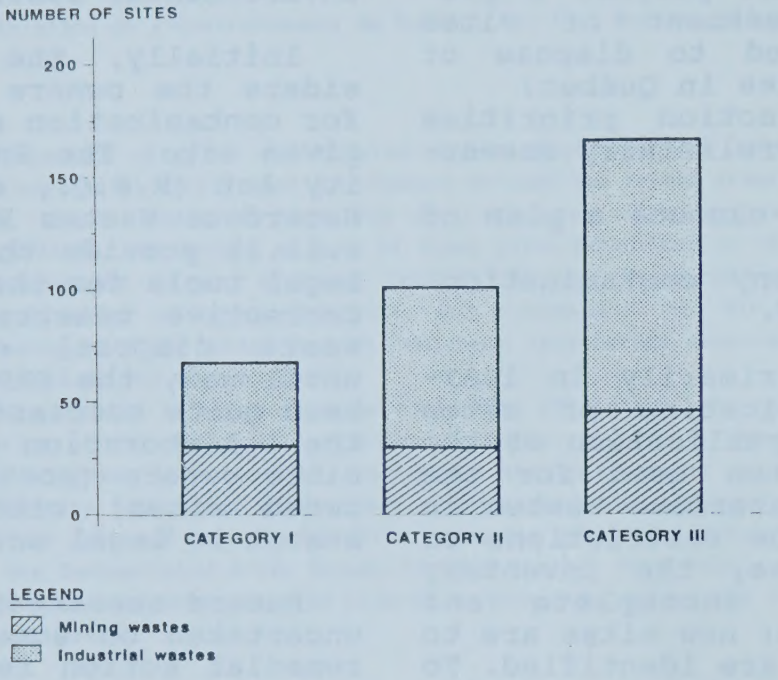
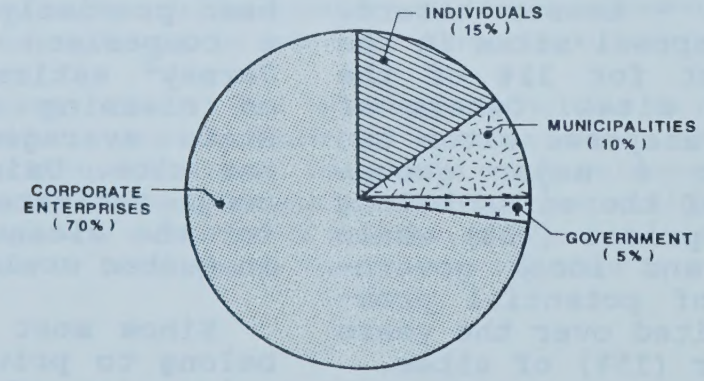


Figure 2
OWNERS OF HAZARDOUS WASTE DISPOSAL SITES



Ministry on the need for remediation actions on their sites and on the degree of decontamination to be achieved before development.

Meanwhile, decontamination carried out in a residential neighborhood of LaSalle in 1986, where houses had to be demolished and contaminated soil excavated, at a cost to the taxpayer of over $10 million, was a clear reminder that an ounce of prevention is worth a pound of cure when it comes to the redevelopment of contaminated land. These events prompted the Ministry to prepare a policy providing guidelines for the redevelopment of former industrial lots which ensures public safety and environmental protection. The GERSOL program (Gestion et Restauration des Sols contaminés) was thus launched in 1987.

THE GERSOL PROGRAM

The phenomenon of closing and decommissioning timeworn industrial installations will be increasingly prevalent all over North America in the years to come. As much as 20% of the country's existing industrial capacity could be closed down during this decade for economic reasons[3].

Over decades of operation, many of these industrial installations used or generated hazardous substances. The discharge of these substances, whether linked to daily operations, accidental spills or their disposal in the factory's yard, has resulted in the contamination of surrounding soil and groundwater.

An important choice had to be made about the eventual status of these decommissioned sites. One solution would be to prohibit all redevelopment of sites where hazardous waste and contaminated soils may be present and turn these lots into "no man's land", fenced and inaccessible. Because a lot of these sites are now found in cities, frequently in downtown areas, prohibited zones would thus become numerous in the heart of prime development land. Managing contaminated sites in such a way would run counter to current trends in our post-industrial society, that is, maximization of urban potential, recovering and recycling of old buildings, return of the population to city centres. Moreover, the rehabilitation of these zones often greatly improves the quality of life for people already living near the contaminated sectors. The disappearance of empty lots and abandoned factories in the heart of cities, greater housing concentration and creation of green spaces are all positive repercussions, not to mention the elimination of sources of contamination likely to threaten public health and the environment.

Furthermore, the attraction of developing these zones is obviously a major incentive leading eventual promoters to take charge of the cleanup process.

The **Contaminated Sites Rehabilitation Policy**[4], made public in March 1988, can be summarized as follows:

- it is desirable to permit the recovery of contaminated sites provided that the quality of soil and groundwater is compatible with planned uses;
- a promoter planning to reuse a former industrial site or any other potentially contaminated land shall first conduct a site study to assess the nature, extent, and current or anticipated impacts of contamination;
- before it is reused, a site contaminated by hazardous substances shall be decontaminated in accordance with the anticipated uses and with the key

criteria established by the Ministry;
- in order to ensure safe decontamination and provide permanent solutions, wastes and contaminated soil shall be handled, treated or disposed of according to the regulations and guidelines of the Ministry;
- studies and work associated with assessment and rehabilitation of contaminated sites shall be carried out by either the owner or the promoter in accordance with guidelines provided by the Ministry.

The Policy document states out the general orientation and framework for effective and secure management of former industrial sites. More accurate guidelines are provided in a series of **Technical Guides** that accompany the Policy.

The key criteria used to determine the relative level of contamination measured in the soil or groundwater have been published in the form of a table giving three sets of values (A, B & C) to define ranges of concentration requiring different levels of action.

Inspired by the approach used in the Netherlands, which seems to be the most advanced country in these matters, the key criteria have been expanded and adapted to Quebec's conditions. They should not be considered as legal standards: they are to be used as guidelines by specialists who must assess the contaminated, sites taking into account site-specific conditions and particularities of the site's planned use. In this respect, the Ministry is also ready to consider the validity of site-specific decontamination criteria established after a detailed risk analysis study.

The Ministry has been incidentally working since 1987 with other governments and the private sector, within the Canadian Council of Ministers in Resources and Environment (CCMRE), in the Industrial Decommissioning Task Force whose goals are to set National decommissioning guidelines and to develop a risk analysis approach for establishing site-specific soil decontamination criteria.

CONCLUSION

The management of hazardous waste landfills or of contaminated sites is well under way in Quebec but there are still challenges to be met.

By its action, the Ministry has sensitized owners of hazardous waste disposal sites or of contaminated land to their liability as regards current or anticipated impacts of contamination on public health or environment.

Hazard assessment has been undertaken on many sites owned by private enterprises which feel responsible for the present situation. However, financial support is lacking for action on sites where present owners do not want to assume the costs to clean up the contamination left by previous owners. Moreover, non-solvent owners who hold many of these sites will declare bankrupcy if they are forced to take action.

One part of the solution is the rehabilitation of contaminated sites where money invested by promoters in the cleanup can be recovered in subsequent redevelopment projects. This approach has been addressed by the Contaminated Sites Rehabilitation Policy. However, the contaminated sites are not always located on prime development land. For these latter, the investments are intended solely to control or

eliminate present threats to human-health and to the environment. The funding of necessary actions on these sites owned by provincial or local governments or by non-solvent owners is not a small challenge. Work is under way within the Ministry and with the Canadian Council of Ministers in Resources and Environment (CCMRE) to address the question. The U.S.A. federal government (EPA) has created SUPER-FUND which is intended for such a purpose[2].

The money spent to date for the management of contaminated sites in Québec (around $25 million in the past three years) is just the tip of the iceberg. Until now, the efforts have indeed focused mainly on hazard assessment studies. These studies often lead to a dead-end since there are no contaminated soil or chlorinated hydrocarbons treatment facilities in Quebec. Substantial cleanup projects realized to date include excavation of contaminated soils and their burial in high security landfills. Confinement techniques have been used successfully on other sites. However, these measures are seen only as transitional to the final solution, which is treatment of hazardous wastes and of contaminated soils.

The other challenge the Ministry therefore addresses is the necessary establishment of treatment facilities by private enterprise. The business opportunity exists, but the NIMBY ("Not in my back-yard") syndrome is the most difficult obstacle to overcome, even if the technologies used are usually safer than many more common industrial processes.

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THE DILEMMA OF GOVERNMENT AGENCIES AS RECLAMATION PROPONENTS
The KAM KOTIA EXAMPLE

LE DILEMNE DES AGENCES GOUVERNEMENTALES FACE A LA RESTAURATION
L'EXEMPLE DE KAM KOTIA

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Abstract:

The acid tailings drainage from the abandoned Kam Kotia mine near Timmins, Ontario is one of the worst cases of its kind in Canada. Due to complicated changes in ownership, the property has reverted to the Crown who is in the process of rehabilitating the site to preclude further environmental degradation of adjacent waterbodies. The rehabilitation design is being completed and consideration is being given to an innovative combination of advanced geopolymers with a reforested cover and an extensive artificial marsh treatment system.

This paper examines the rehabilitation design in terms of its technical and policy rationale. The relatively new reclamation approach combined with the unusual position of the government as both the rehabilitation proponents and the review and approval body provide an excellent portrayal of the interactions among sometimes conflicting reclamation objectives relating to environmental protection, government policy and economic efficiency. Examples of the challenges and dilemmas faced in reaching an acceptable solution are discussed in the broad context of reclamation within the Province.

Résumé:

Le drainage des résidus acides de la mine abandonnée de Kam Kotia près de Timmins, Ontario, représente l'un des pires cas de ce genre au Canada. A cause de nombreux changements de propriétaires, le site est retourné aux mains de la Couronne qui travaille présentement à la réhabilitation du site afin de prévenir une plus grande dégradation environnementale des plans d'eau adjacents. Le dernier projet de réhabilitation est maintenant complété et il innove grâce à la combinaison des géopolymères avec une couverture reboisée et l'instauration de marais artificiels.

Cet article examine le projet de réhabilitation en termes de techniques et de politiques rationnelles. Notre nouvelle approche en restauration combinée avec l'inhabituelle position du gouvernement en matière de projets de réhabilitation et les agences qui pourvoient les fonds et approuvent les projets, donnent une excellente représentation des interactions parfois contradictoires concernant la protection environnementale, les politiques gouvernementales et l'efficacité économique. Des exemples de défis et de dilemmes face à l'atteinte d'une solution acceptable sont discutés dans un large contexte de restauration l'intérieur de la province.

NOTE: The CLRA Conference committee regrets that a full copy of the paper was not received in time to be included in the proceedings. Copies of the paper will be distributed at the conference. For more information, we suggest you contact the author at 416-839-7163.

MINING AND LAND RECLAMATION IN NEW ZEALAND

L'EXPLOITATION MINIERE ET LA RECUPERATION DES TERRES EN NOUVELLE-ZELANDE

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Abstract:

New Zealand was the scene of gold rushes in the 1860s. This played an important part in settling the country and establishing its financial base. Following the gold rush era, mining was relatively insignificant in the country's economy which was, and still is, dominated by agricultural production.

Land reclamation following mining was optional until 1971 when the country's mining legislation was reviewed. The lack of reclamation caused much evironmental damage and public disenchantment with mining. Reclamation is now a licence requirement for all new mining projects.

The underlying requirement of the 1971 New Zealand Mining legislation is that land has to be restored as good as or better than its pre-mine state. Because its land resources are very important to the economy, mined land has, in most cases, to be restored for productive purposes. All mining proposals are open to public scrutiny and enquiry before mining licences are granted.

Achieving reclamation results which meet mining licence requirements calls for detailed planning, research into soil and overburden resources and their uses, and careful implementation of the reclamation programmes.

Experience in planning and research into recreating productive land that is capable of sustaining pre-mine productivity is discussed and examples given.

Résumé:

La Nouvelle-Zélande a été la scène de ruées vers l'or dans les années 1860. Cela a joué une part importante dans la colonisation du pays et dans l'établissement de sa base financière. Suite à l'époque de la ruée vers l'or, l'exploitation minière a été relativement insignifiante dans l'économie du pays qui était et qui est toujours dominée par la production agricole.

La récupération des terres affectées par les opérations minières était optionnelle jusqu'en 1971 alors que la législation minière du pays a été revisée. Cette lacune en matière de restauration a causé beaucoup de dommages environnementaux ainsi que le désenchantement du public face à l'exploitation minière. La récupération fait maintenant l'objet d'une exigence pour accorder un permis d'exploitation pour tous les nouveaux projets miniers.

L'exigence de base de la législation minière de Nouvelle-Zélande de 1971 est que le territoire doit être remis dans un état identique sinon meilleur à celui d'avant les opérations minières. Etant donné que les ressources territoriales sont très importantes dans l'économie, les terrains miniers abandonnés doivent être remis en état de production végétale. Toutes les propositions d'exploitation minière sont ouvertes à l'examen public et au questionnement avant que les permis d'exploitation soient accordés.

Atteindre des résultats de récupération qui rencontrent les exigences des permis d'exploitation minière demande une planification détaillée, de la recherche sur les sols et sur l'utilisation des ressources, et une réalisation soignée des programmes de récupération.

L'expérience en planification et en recherche sur le renouvellement d'un territoire productif semblable à e qu'il y avait auparavant fera l'objet de la discussion et des exemples seront apportés.

INTRODUCTION

New Zealand is a small country covering an area of a little over 100,000 square miles. That is about one-quarter of the size of the Province of Ontario. It is a country which is fortunate in being endowed with much natural beauty - geothermal and volcanic wonders, mountains and glaciers, beautiful lakes and fiords, sparkling clear rivers, montane vegetation, native bush and lush pastures, and clean air. Acid rain is unknown, and with a few minor exceptions which are also seasonal in nature, there is no air pollution from industry, the latter being strictly controlled by legislation.

Situated in the temperate zone, New Zealand enjoys an equitable climate which is affected by maritime influences. This is to be expected since it is an island nation in the South Pacific. Pastoral farming is a major land use - some 60 million sheep are farmed for wool and meat. It has a large dairy industry, and also produces venison from farmed deer and beef. The country is self-sufficient in grain production and has a strong and expanding horticultural industry noted for its kiwifruit and apple production as well as a growing viticultural industry.

Besides its agricultural and horticultural production, New Zealand has over 1 million hectares of exotic pine forests which produce substantial quantities of pulp and paper as well as sawn timber. In all, these land-based activities produce nearly 70% of the country's export revenue. It is little wonder then that the importance of production from land has a major influence on the public's perception of standards of rehabilitation of land affected by mining. It seems most people in New Zealand have a relative or know someone who is farming.

However, like most agricultural producing nations, the New Zealand primary sector is financially depressed. Mining in New Zealand is not a major economic activity. The principal types are coal, mineral sands and gold mining. At the present time it is gold mining which is expanding quite rapidly, with an equal emphasis on the mining of alluvial and hard rock gold.

GOLD

The existence of widespread gold ore bodies in New Zealand is not surprising as it is part of the circum-pacific mobile belt. South Island vein deposits are associated with Paleozoic sediments and meta-sediments while North island ores are associated with Tertiary, to recent, epithermal activity.

New Zealand experienced its first gold rush in 1860, just two decades after European settlement. This followed similar gold rushes in British Colombia, California and Victoria, Australia. The wealth generated from the gold discoveries played an important part in establishing early New Zealand's financial base. Indeed, it is claimed that, even today, Dunedin, a small city of canny Scots, which was close to the rich gold fields of Central Otago, still plays an important role in the financial affairs of the country.

Following a decade of feverish activity associated with the gold rushes, gold mining declined in importance and farming evolved as the base of the country's economy. A minor resurgence of gold mining

occurred in the two decades from 1930 with the advent of large Yuba-type bucket dredges. These worked alluvial deposits on old river and glacial terraces, flood plains and river systems, in Otago and Westland. Substantial quantities of gold were recovered but in the process large tracts of formerly productive land were laid to waste by the huge piles of tailings left behind by the dredges.

The degradation of land resulted from mining legislation which allowed mining companies the option to rehabilitate land following mining or paying the sum of $75 per hectare in lieu. It is not surprising then that mining companies chose to pay the levy into Government coffers. The degradation of land has had a significant environmental impact and led to a general disenchantment by the public, with the mining industry - a legacy which remains with the industry today, notwithstanding the changes to the mining legislation in 1971 which tightened environmental and rehabilitation requirements.

By the early 1950's, most of the dredging operations had ceased because of unprofitability occasioned in part by the fixed price of gold. Only one dredge, the "Kanieri", remained, and this operated until 1982 when it reached the end of its economic life. This coincided with it completing the dredging of the richest portion of its last remaining licence area. I became involved with this dredging operation for the last five years of its working life after accepting the challenge to work with the company to meet rehabilitation requirements imposed as a condition on the final mining licence it obtained. This licence, issued under the 1971 Act, required the land to be rehabilitated.

OIL & COAL

The oil shock crisis of the early 1970's led to a re-appraisal of New Zealand energy sources. At that time the nation's primary energy source was hydro-electricity and 95% of our liquid fuels were imported. Coal provided a small but significant amount of energy particularly for our processing industries. The discovery of the huge off-shore Maui gas and condensate field and later smaller on-shore fields means that today New Zealand is 50% self sufficient in liquid fuels. This is due in part to our large synfuel plant which is the world's first large scale gas-to-gasoline plant.

While the oil industry was undertaking extensive exploration, and in this it has been unusually successful, a major re-appraisal of our coal reserves was underway. Known reserves of high grade bituminous coals now stand at 160 million tonnes while subbituminous coal reserves stand at 720 million tonnes. Much more significant, in terms of their potential for liquefaction to produce liquid fuels, are our lignite coal reserves which presently stand at 5 1/2 billion tonnes.

Coal is subject to a separate Mining Act. Currently a little over 2 million tonnes of coal are mined annually, predominantly by open cast methods. Underground mining is largely confined to winning high grade bituminous coals.

The largest coal miner in New Zealand is the recently corporatised state-owned Coalcorp. It mines approximately 80% of the country's annual production and most of this goes to two thermal power stations run by state-owned Electricorp. Regrettably Coalcorp has a bad record when it comes to

rehabilitation and it has only been in the past decade that it has made any significant effort to rehabilitate land it has disturbed. This rehabilitation has largely been of a cosmetic nature where earlier waste dumps and overburden stockpiles have been tidied up. Subsequent to corporatisation it is expected that a much higher standard of rehabiliation will be required of Coalcorp.

MINERAL SANDS

For two decades New Zealand has had a substantial mineral sands industry based on titano-magnitite sands. These have been mined by two companies from coastal deposits in the North Island. The mineral is mined and concentrated and at its peak some 3 1/2 million tonnes of 56% iron concentrate was exported annually. This was used mainly by Japanese steel mills as a component ore for their blast furnaces. During this time a company, New Zealand Steel, has refined a metallurgical process whereby iron sand concentrate is converted into iron and steel in electric arc furnaces. New Zealand Steel has just completed an expansion programme which will result in the production of 700,000 tonnes per year of high grade iron and steel in a state-of-the-art steel mill. This will require about 2 million tonnes of iron sand concentrate each year.

One of the sand mining companies, Waipipi Iron Sands, has recently closed after 17 years operation, during which it mined some 800 hectares of deposit. Its closure arose because of diminishing demand for its concentrate from Japanese steel mills. I became involved with this company in 1981 when I undertook an audit of its rehabiliation work over its first 10 years of mining. Both mining companies have good records for rehabilitation and have been good for the New Zealand mining industry in demonstrating to the public that responsible mining, complying with the 1971 mining legislation, can be environmentally acceptable.

REHABILITATION

As I have already indicated, rehabilitation in New Zealand was optional until the mining legislation was reviewed and the new Act came into being in 1971. Initially few mining licences were issued under the new Act and it has only been as a result of a big upsurge in interest in gold mining over the past 5 years that has seen the mining industry on a growth phase. As a consequence there has been a steady growth and development of land rehabilitation skills over this period, with it increasing significantly over the past few years. I have been fortunate in being a central figure in the field and have thus had an active involvement in most of the major new mining projects.

Because of the importance of farming to the economy, it is not surprising that rehabilitation of mined land for further farming uses has been a major issue. The initial perception of what rehabilitation should achieve revolved around recreating a soil profile as close as possible to the original undisturbed state. This meant a careful conservation and recovery of the soil resource and replacing over the rehabilitated land in its natural sequence.

A number of us working in rehabilitation challenged this approach as it presumed that the natural soil profile was ideal. We believed that in many cases this was not so and that, given the opportunity that rehabilitation offers, we could improve on

nature. Later I shall illustrate this viewpoint.

It is not surprising, given the importance of farming to the New Zealand economy and the strength of our agricultural science skill, that the approach to rehabilitation has a strong agronomic bias.

One of the great advantages I experience as a practitioner is the current expansion of new projects. This provides me with the opportunity to be involved in the early planning of a project rather than attempting to tidy up an existing problem. As a result it is possible to achieve significantly better results.

It is very pleasing to be part of a project team for a new mining venture and being part of an integrated planning process. Having been involved in a number of such projects I think I know what a geologist feels like when mining commences - the moment of truth arrives!!

Once the scope of the rehabilitation requirements has been determined, the approach I adopt is to establish a multidisciplined team of consultants to undertake baseline data collection and evaluation prior to developing the rehabilitation plan in conjunction with mining personnel.

Environcare Consulting Group, which I have established, comprises a group of independent consultants with specific skills. These include pedology, soil science, geo-soil science, botany, terrestial and aquatic biology, agronomy and landscape architecture. Not all of these disciplines work on a project. It depends on the specific skills required and the nature of the project. To date this approach has proved to be particularly successful in achieving first-class, cost-effective results and is now becoming a model for the New Zealand industry.

REHABILITATION RESEARCH

Because rehabilitation in New Zealand is to date relatively new and certainly limited in scope, little research has been undertaken. As a consequence skills are built up from overseas visits and the tried and true "suck and see" approach. While agricultural research is a sizable industry in New Zealand, the demands for the research dollar and suitable personnel means there has been only limited work undertaken.

Some important work has however been done on the effects of stockpiling of topsoil by staff of the New Zealand Soil Bureau. J.P. Widdowson[1], D.J. McQueen[2] and D.J. Ross[3] have concluded that stockpiling of topsoils have little effect on the chemical and physical properties of the soils and although microbial biomass is slow to recover to original levels there is generally sufficient available N to support initial stages of plant growth.

R. Fitzgerald[4] found that a wide range of common legumes, particularly of the clover family, are suitable species for use as nurse crops for revegetating dredge tailings.

CASE STUDY 1 KANIERI GOLD DREDGING LIMITED

In becoming a consultant to Kanieri Gold in 1978 I took up a challenge to help the company meet, for the first time, rehabilitation requirements. These were part of the conditions set for a new licence it obtained under the 1971 Mining Act. Their large Yuba-type bucket dredge was working alluvial ground 30 metres

deep in the bed of the Taramakau River. It produced coarse tailings comprising material ranging from small (12mm+) to coarse gravel, cobbles and boulders up to 1/2 a metre in size. The fines (-12mm), which had passed through the gold recovery system, were discharged into the dredge pond via the tail sluices.

The soils on the unworked ground were limited in volume and were found only on islands and beaches away from the main river channel. It comprised fine sands and silts and was often mixed with gravels. It was immature, having little structure and organic matter. Its average depth, taken over the whole site, was no more than 150mm.

The licence conditions required the company to spread a metre of fines over the levelled tailings, with the soil material being spread over the fines. I questioned the soundness of these rehabilitation requirements as I considered they were inappropriate but the Mines Inspectorate were unwilling to review the conditions.

The first 6 hectares were rehabilitated in accordance with the licence conditions. This required collaboration with the dredge engineers who installed sand wheels, to recover the fines previously discharged into the dredge pond. These wheels operated in surge chambers in the twin tail sluices. Initially insufficient fines were recovered, so only 300mm of fines were placed over the levelled tailings.

As I expected, the results were disappointing. The vegetation, ryegrass and clovers, was difficult to establish and growth was below expectations despite optimum fertiliser and soil pH levels.

In evaluating the cause of the poor results I identified a number of limiting factors. The most significant of these was the physical characteristics of the soil used to surface the rehabilitated land. It was very fine, structureless material which was subject to surface sealing under high intensity rainfalls. These falls occur frequently under the 3000mm of annual rainfall at the site. High runoff and erosion was experienced. Soil through-drainage and aeration were poor, with consequent poor root development. In addition, there was the problem of water movement inhibition due to the sharp textural boundaries between the soil and the fines and, to a lesser extent, between the fines and the underlying coarse tailings.

Taking a lead from R.E. Fitzgerald's work for the Forest Research Institute in successfully establishing legumes (including Trifolium sp.) on course tailings, I considered a better rooting medium could be developed using the fines mixed with the coarse tailings alone. I put my proposal to the Mines Inspectorate and was able to persuade them to permit it on a trial basis.

Working with the dredge engineer, we were able to increase the volume of fines recovered. These were mixed with the coarse tailings using a D9E Caterpillar with blade and rippers. The surface was levelled and then heavy-rolled with a 7 tonne roller to push the larger stones and boulders below the surface. Molybdic superphosphate at the rate of 600kgs/ha was applied immediately and this was followed by broadcast seeding of a clover dominant mixture of clovers and ryegrasses.

Establishment was excellent and subsequent growth was very good. Although no measurements were made over a season, it was estimated

that dry matter production was of the order of 17,000kgs per hectare per year. This far exceeded what was being achieved elsewhere in the immediate locality and equalled top producing pastures anywhere in the district. The success was attributed to the improved drainage and aeration of the rooting medium.

Because of the success of the rehabilitation, the licence conditions were amended. As well as improving the end result, it achieved significant cost savings for the company as well as demonstrating that good rehabilitation does not necessarily mean recovering and using the soil resource in a conventional manner.

CASE STUDY 2 WAIPIPI IRON SANDS LIMITED

My association with this project came about as a result of undertaking a full audit of their previous ten years of rehabilitation. The company mined a coastal titanomagnetite sand deposit immediately behind the foredunes. The sands, 9 meters in depth, overlay a mud-stone basement. They were mined using two suction cutter dredges feeding a floating concentrator plant. An average of 900mm of rain is expected each year.

A thin layer of organic rich loamy sand overlay the sand deposit. This was dozed to either side of the 300m wide mine path. The levees so formed contained the water of the 5 hectare dredge pond.

The mining operation removed about 10% of the ore volume but this was compensated by a small swell factor in the tailings so little overall loss in height of the land occurred.

After the tailings drained they were levelled and contoured to provide surface drainage. Then the soil from the levees was dozed over the tailings surface. As the soil volume was limited, it was difficult to get an even spread of soil across the site. Because of the exposed nature of the site, wind erosion was a serious problem. Frequent on-shore winds of 30-65k.p.h. were experienced. This problem was met using a mixture of quick growing cereals (oats and barley) sown with compound fertiliser to provide surface cover. Even so this cover was often lost to the salt laden winds and abrasion from moving sand and resowing occurred as many as fifteen times before success was achieved.

Permanent pasture comprising a mixture of clovers and grasses was direct-seeded into the cover crop when it was 150 - 200mm in height. In all 500 kilogrammes of 12.10.-10.9 N.P.K.S. fertiliser was used in the establishment period. Pasture establishment was generally very successful and regular stock grazing was practised 18 months after seeding.

Within a year of grazing commencing, a stock health problem emerged. This was identified as a significant copper deficiency. Young stock failed to grow and breeding stock suffered infertility problems. Copper was added to the annual fertiliser dressings and the problem overcome. It transpired that there was a marginal deficiency in the soils of the district but this was not a problem under the low intensity stocking practices. Following mining and the very effective rehabilitation which markedly increased pasture production, the marginal copper deficiency became a gross one.

Waipipi Iron Sands rehabilitated 800 hectares of mined land before it ceased production recently after 17 years operation.

It was the first major mining project in New Zealand to operate under the 1971 Mining Act. Its achievement in attaining a high standard of rehabilitation has done much to restore the New Zealand public's image of the mining industry and its care of the environment.

CASE STUDY 3 MARTHA HILL

This joint venture project was managed by Amax (NZ) Limited and I was responsible for co-ordinating the development of the rehabilitation plans. Joining the project as a consultant in 1983, it was my first experience in working in an integrated planning team.

The project will see the mining of an epithermal gold and silver deposit. Martha Hill was first mined in 1867 and operated until 1952 using underground methods which reached a depth of 600 metres. The new mining proposal will see the open pitting of the top 200 metres of the old workings. The mine will have a surface area of 31.5 hectares and is expected to yield $600m of gold and silver over its 15' years mine life.

Mining will produce over 20 million tonnes of waste rock and 8 million tonnes of tailings. The tailings pond will cover 60 hectares and the waste rock dump a further 70 hectares.

The soils on the waste disposal site were derived from Holocene and late Pleistocene volcanic ash with the alluvial soils developing from tephra and weathered rhyolite and andesite.

Initially it was thought that little of the soil, which was up to 2 metres thick, would be available for rehabilitation as it was planned to use it for its leachate attenuation properties under the waste rock dump and tailings pond. This presented a challenge as to how the land could be rehabilitated to a productive state. An average of 2150mm of rain fall each year.

In the course of early site inspections I made two important observations. One was the range of plant species colonising oxidised waste rock exposed by earlier prospecting work on the mine site. The second was that a small tailings pond, created for the trial processing of the ore, also had a range of plants growing on it. This prompted speculation as to the potential of these materials as rooting media.

Demonstration field trials were undertaken to evaluate a range of species which the oxidised waste rock and tailings would support. These trials proceeded while full chemical and physical analyses of the materials were undertaken. Later, fully replicated field trials were initiated to determine optimum fertiliser treatments and soiling depths.

Early results showed that, in the Waihi environment, soiling depth was not a critical factor where pasture production was the intended land use. Soil was however beneficial in the initial establishment of the pasture.

The field trial results were of particular importance in providing the confidence that the conceptual rehabilitation planning was sound. Final rehabilitation plans were prepared in conjunction with the mining engineers and a landscape architect. A critical factor in the plan was the scheduling of the waste rock material to minimise overall costs. The plan was presented as part of the Martha Hill Project Environmental Impact Report, 1985. After this was audited by the Commissioner for

the Environment, a Mining Licence was applied for and granted in July 1987. Mining commenced in this year with the first bullion being produced in May.

CONCLUSIONS

In New Zealand, we do not have the history of experience other countries have in mine land rehabilitation. We have tried to use our skills in agricultural science and associated disciplines to best advantage. In utilising multi-discipline planning teams we have been able to achieve worthwhile and productive rehabilitation. In this we have been fortunate in being involved from the outset of project planning and have thus been part of an integrated planning process which brings with it many advantages that enhance the results achieved.

In addition, it can be seen from the examples I have given that, generally, we are not working in arid conditions. While this spares us the many problems associated with that environment, working in high rainfall areas also has its own set of problems.

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THE PROPOSED AGGREGATES ACT AND THE FUTURE OF PIT AND QUARRY REHABILITATION IN ONTARIO

PROPOSITION D'UNE LOI SUR LES AGREGATS ET L'AVENIR DE LA REHABILITATION DES CARRIERES ET SABLIERES EN ONTARIO

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Abstract:

The Pits and Quarries Control Act was enacted in 1971 in order to minimize the social and environmental impacts of aggregate extraction and ensure that pits and quarries are rehabilitated. There is no doubt that this legislation has greatly improved the situation and a lot of rehabilitation is occurring. However, the existing legislation is inadequate in many ways including several deficiencies that lessen the ability of the Ontario Ministry of Natural Resources to encourage and require rehabilitation.

The proposed Aggregates Act, which will replace the Pits and Quarries Control Act, should greatly increase the quantity and quality of rehabilitation and close existing loopholes. Progressive rehabilitation will be required, not just encouraged. Licensees will be liable for the costs of rehabilitating sites that they have abandoned. The minimum standards for rehabilitation have been upgraded and the regulations include special requirements for agricultural after-uses. The Act also provides for the establishment of a fund for the rehabilitation of abandoned pits and quarries. In addition, the Ministry of Natural Resources has greater powers of enforcement to ensure that these provisions are adhered to.

This paper will highlight these and other improvements of the proposed Aggregates Act that will greatly improve the rehabilitation of pits and quarries in the Province of Ontario in the years to come.

Résumé:

La loi sur le contrôle des carrières et sablières a été promulguée en 1971 afin de minimiser les impacts sociaux et environnementaux de l'extraction d'agrégats et d'assurer la rèhabilitation des carrières et sablières. Il n'y a aucun doute que cette législation a grandement amélioré la situation et présentement beaucoup de projets de réhabilitation sont réalisés ou en cours. Cependant, la législation existante est inadéquate de différentes manières, notamment par plusieurs lacunes qui diminuent la compétence du ministère des Ressources naturelles de l'Ontario en matiére d'exigence et d'encouragement à la réhabilitation.

La loi sur les agrégats proposée, qui remplacera la loi sur le contrôle des carrières et sablières, devra augmenter considérablement la quantité et la qualité des projets de réhabilitation et combler les lacunes existantes. Une réhabilitation progressive sera non seulement encouragée mais exigée. Les détenteurs de permis seront responsables des coûts de réhabilitation des sites qu'ils auront abandonnés. Les standards minimums de réhabilitation ont été haussés et les règlements incluront des exigences spéciales pour une utilisation agricole après usage. La loi prévoit également l'établissement d'un fonds monétaire afin de réhabiliter les carrières et sablières abandonnées. En plus, le ministère des Ressources naturelles aura un pouvoir accru afin de s'assurer du respect des dispositions de la loi.

Cet exposé soulignera donc les changements proposés par la loi sur les agrégats qui vont grandement améliorer la réhabilitation des carrières et sablières en Ontario pour les années à venir.

PREAMBLE

An Act to revise the Pits and Quarries Control Act was first suggested by the Ontario Mineral Aggregate Working Party in 1976. Since then it has been the subject of much debate amongst politicians, agencies, industry and the public who are interested in the aggregate industry in Ontario. After much work by the Ministry of

Natural Resources the Aggregates Act is now ready to be introduced to the Legislative Assembly through "First Reading".

However, at the time of writing (June 1988) this has yet to happen. Until such time the contents of new legislation are confidential. As a result, this paper is based on Bill 127 which did receive First and Second Reading in 1980 but was not passed into law. It is anticipated however that the intent and major provisions of that proposed legislation and the Aggregates Act are essentially the same.

INTRODUCTION

Southern Ontario represents the highest demand area for aggregates in Canada. In 1986 about 18 tonnes of sand, gravel and crushed stone was consumed per capita[1]. The value of the annual production of sand, gravel and crushed stone in Ontario was estimated to be 703 million dollars in 1986; an amount surpassed by only gold and nickel[2]. When other structural materials such as cement, lime and clay are included the value rises to nearly 1.5 billion dollars. In comparison to other commodities however, aggregate has a very low value in relation to volume, only extraordinarily high tonnages result in such a high production value. Over half the cost of delivered aggregate is for transportation. As a result it is a major economic asset if aggregate can be extracted close to the market; the urban areas. Provincial Policy states that it is necessary to maintain sources of supply as close to markets as possible and that aggregates should be available to the consumers of Ontario at a reasonable cost[3]. Unfortunately the proximity of extractive operations to urban areas results in many social and environmental problems and potential for land use conflicts. The aggregate industry is very visible and often has a poor public image.

A number of factors and trends led to the involvement of the Provincial Government in aggregate resource management in the late 1960's. Among these factors were:

- increasing environmental awareness of the general public;
- increasing numbers of rural, non-farm residents;
- a rapidly growing economy and directly related growth in the demand for aggregates and the size of aggregate operations;
- unregulated operation of pits and quarries;
- restrictive actions by local governments that if allowed to continue would have resulted in aggregate shortages.

The Pits and Quarries Control Act[4] (P.Q.C.A.) was passed in 1971. The main objectives of this legislation were to minimize the environmental and social impacts of aggregate operations and to require the rehabilitation of pits and quarries.

As with any new legislation it gradually became apparent that there were inadequacies with the P.Q.C.A. Changes in industry practices and attitudes did not occur overnight and there was a public perception that the Act was ineffective, especially in regards to rehabilitation. This is not to insinuate that the legislation did not result in positive changes. Even most anti-industry groups and neighbours of aggregates operations would probably agree that things have improved since the early 1970's. There are many excellent examples of pits and quarries that have been reclaimed to productive and attractive after uses. Ontario is recognized as a leader in aggregate resources management throughout North America.

The next phase in the government's involvement in aggregate resources management was the work of the Ontario Mineral Aggregate Working Party which was formed in 1975 to review the legislation and assess various concerns that had been raised. This group was made up of representatives from provincial and municipal governments, industry personnel and public interest groups. They travelled the province seeking input from all levels of government, public and industry. The Working Party's report formed the basis for the development of a resource management strategy for mineral aggregates.

This strategy can best be described as a dual approach which consists of the proposed Aggregates Act and the Mineral Aggregate Resources Policy Statement. The new Act would replace the P.Q.C.A. and provide for more stringent control of pit and quarry operations and their rehabilitation. The Policy Statement was released under Section 3 of the Planning Act, in May, 1986. This Policy provides a framework for the planning of aggregate resources and extraction through the municipal planning process.

ASSESSMENT OF REHABILITATION UNDER P.Q.C.A.

Before discussing how the Aggregates Act will deal with the rehabilitation of aggregates operations, it is interesting to review past assessments of the P.Q.C.A. with regard to rehabilitation.

The Ontario Mineral Aggregate Working Party conducted an indepth review of industry activities and public perceptions in 1976, 5 years after the introduction of the P.Q.C.A. Although they did not have access to definitive statistics they reported that: "while there are some notable examples of progressive and imaginative rehabilitation, it would appear that such operations still represent a small fraction of the industry and that there is much misunderstanding as to what is the true meaning of the words progressive rehabilitation"[5].

A more quantitative study was completed in 1979 by W.E. Coates and O.R. Scott. This study was commissioned by the Ministry of Natural Resources and evaluated 258 licenced pits and quarries in central Ontario. The study found that major increases in rehabilitation work had occurred since the passage of the Act and documented several successful rehabilitation projects. However, most of the rehabilitation was being done by larger companies and the Act did not appear to have forced widespread rehabilitation on the part of smaller operators. The study also noted a lack of the successful establishment of proper or acceptable plantings. The authors also observed that the lack of an exact definition of rehabilitation had resulted in confusion on the part of operators and the public[6].

In 1985 a Ministry of Natural Resources study team completed an Evaluation of the Rehabilitation Incentive System of the Pits and Quarries Control Act using detailed data from actual pit and quarry operations across the province. The study found that in a four year period only 41 per cent of operators had done any rehabilitation and that in 1984 only 19 per cent reported any rehabilitation (includes non-active licences)[7]. In 1986 over 7 million dollars was spent on rehabilitation across the province. However, if the trends noted in the 1985 study have continued, this amount was spent on a relatively small number of sites and largely reflected the

costs of hauling and dumping of fill material.

Ministry of Natural Resources enforcement activity since the Act was introduced has not concentrated on rehabilitation. With the exception of a few charges that have been laid for contravention of Regulation 9, that requires topsoil to be retained for rehabilitation, all other charges relate to the operational aspects of aggregate operations such as fencing, setbacks and operating without a licence. The reason for this is partially explained by problems with the wording of the regulations made under the Act.

It would appear that based on these studies and other observations that the P.Q.C.A. has not been completely successful in requiring rehabilitation which is one of the main objectives of the legislation. While there are many good examples of pit and quarry rehabilitation projects, there does not appear to be widespread commitment to rehabilitation by the aggregate industry as a whole.

THE AGGREGATES ACT

The proposed Aggregates Act will replace the P.Q.C.A., Part VII of the Mining Act (quarry permits) and The Beach Protection Act. The new Act has four purposes:

1. To provide for the management of the aggregate resources of Ontario;
2. To control and regulate aggregate operations on Crown and private land;
3. To require the rehabilitation of land from which aggregate has been excavated;
4. To minimize adverse impact on the environment in respect of aggregate operations.

Many of the improvements in the Aggregates Act are simply the result of seventeen years of experience in working with the P.Q.C.A. Definitions have been clarified and sections reworded so that the provisions of the Act now more accurately reflect the intent of the legislation. Loopholes have been closed and ambiguities eliminated. The result will be a more effective and workable piece of legislation.

These changes and improvements will increase the effectiveness of aggregate resource management in all aspects of the legislation, however, the potential for improvements in rehabilitation will be particularly noticeable.

The remainder of this paper will highlight some of the provisions of the proposed Aggregates Act that will have an impact on the rehabilitation of Ontario's pits and quarries in the years to come.

Rehabilitation is Defined

The Ontario Mineral Aggregate Working Party Report and the Coates and Scott Rehabilitation Study both concluded that the lack of a definition of rehabilitation in the P.Q.C.A. had resulted in confusion amongst the operators and general public. The Aggregates Act clarifies the situation and rehabilitation is defined:

"rehabilitate" means to treat land from which aggregate has been excavated so that the use or condition of the land,

a) is restored to its former use or condition, or
b) is changed to another use or condition that is or will be compatible with the use of adjacent land;

"progressive rehabilitation" means rehabilitation done sequentially in accordance with this Act, the regulations, the site plan and the conditions of the licence or permit during the period that aggregate is being excavated.

Security Deposit Incentive System

The rehabilitation security deposit system that is presently in place under the P.Q.C.A. will remain essentially unchanged under the proposed Aggregates Act.

Under this system every licensee must contribute to a security fund to ensure the rehabilitation of the pit or quarry. The assessment rate is equal to 8 cents per tonne of material removed from the pit or quarry. Payment into the account must continue until the balance reaches the minimum of $1,000 per hectare requiring rehabilitation. Once this minimum is reached, the licensee is eligible to be credited for costs incurred by rehabilitating the property, provided that the required minimum deposit is maintained. If no rehabilitation is done payment into the account continues up to a maximum of $6,000 per hectare requiring rehabilitation. Under this system there are two main financial incentives for the operator to perform progressive rehabilitation. First, any money that is spent on rehabilitation can be credited to the operator provided that the minimum requirement per disturbed hectare is maintained. The second incentive is that deposit requirements can always be reduced by rehabilitating land so that the area requiring rehabilitation is kept at a minimum.

Once the site is rehabilitated in accordance with the Act, Regulations and site plans the remainder of the security deposit is refunded to the operator. The new Act will correct an inequity of the P.Q.C.A. by requiring that holders of wayside pit permits also maintain a security deposit. (Waysides are temporary permits that are issued to public authorities for specific road projects.)

The security deposit system is one element of the P.Q.C.A. that has undergone significant evolution since the implementation of the Act. The assessment rate and deposit requirements have gradually been increased to more accurately reflect the cost of rehabilitation and provide a greater incentive. The type of work for which credits can be obtained has also evolved over the years. The continuing trend away from cosmetic rehabilition (e.g. berms, tree screens, ornamental plantings, property improvement) and towards "real" rehabilitation (e.g. sloping, grading, establishment of vegetation) must continue if this system is to be effective and encourage progressive rehabilitation.

Rehabilitation Where Licence is Revoked

Under the P.Q.C.A. the security deposit may be forfeited and used for rehabilitation when the rehabilitation program has not been carried out. However, there are two main difficulties with the implementation of this section. First, the Act does not give the Minister or his agent right of entry, so that the landowners permission is required. Secondly, the amount of work that can be done is limited by the amount in the security deposit which is often at or below the minimum since the assessment rate was only 2 cents/ton until 1981 and large rehabilitation claims were given for cosmetic rehabilitation (berms) in past years. The remaining money is often insufficient to

complete substantial rehabilitation.

The Aggregates Act remedies both of these problems. The Ministry or a person authorized by the Minister may enter upon a site to perform rehabilitation. In addition the Minister may perform such rehabilitation as the Minister considers necessary and the cost of the work is a debt due to the Crown if there are not sufficient funds in the security deposit account.

This new system should greatly decrease the incidents of properties being abandoned without the rehabilitation being completed.

Improved Wording and Clarification

The improvements and clarifications that have been obtained through revised wordings are too numerous to discuss in detail. However, one example that relates directly to rehabilitation and typifies the intent of the new legislation is the change in the regulation dealing with progressive rehabilitation. The regulation made under the P.Q.C.A. states:

> "Every operator of a pit or quarry shall, where possible, while the pit or quarry is in operation rehabilitate the pit or quarry..."

The wording "where possible" creates a legitimate defence for any operator and renders the section virtually useless. The revised wording under the Aggregates Act makes a much stronger statement;

> "Every licensee and every permittee shall perform progressive rehabilitation and final rehabilitation on the site..."

Progressive rehabilitation will be a requirement of the new legislation not just encouraged as it was in the past. In addition, the Act will allow the Minister to require that a licensee undertake rehabilitation where the Minister deems that progressive rehabilitation has not been adequate. It would be an offence for the licensee not to comply with such an order.

Improved Rehabilitation Standards

The P.Q.C.A. provides very minimal standards for rehabilitation. Faces have to be sloped to a 45 degree angle, topsoil replaced and the area planted with trees, shrubs, legumes or grasses. While many operators did go beyond these minimum standards there was no legislative authority to require anything more effective or elaborate. The regulations under the Aggregates Act will:

a) require that final excavation face for pits be sloped to not more than thirty degrees off horizontal;
b) require that topsoil and subsoil are stripped separately and that a sufficient depth of topsoil is used to grow and maintain vegetation adequate for rehabilitation purposes, including erosion control;
c) require special provisions for agricultural rehabilitation (proposed after use for about 50% of sites) including adequate drainage, alleviation of compaction and use of legumes in revegetation.

Site Plans

The P.Q.C.A. and the Aggregates Act rely heavily on the use of site plans to ensure suitable operating practices and rehabilitation. Under both pieces of legis-

lation the operator must operate in accordance with the site plan upon which his licence is based. These plans include one page dedicated to showing how the site will be rehabilitated. Under the present legislation there is no requirement to update or refine these plans if site conditions or land use priorities change over time. There are many plans in existance that were made in the early 1970's when standards for the plans were lower. The typical plan of the era consists of the property boundaries, minimum required setbacks, some provisions for screening or phasing of the operation and a "best guess" at the proposed after use. Rehabilitation is usually explained as sloping to 45 degrees and respreading topsoil (if available).

Under the Aggregates Act the legislative requirements for site plans are much more elaborate and detailed than at present. (Although site plans prepared over the past few years should meet the new requirements). In addition all existing licenses will be required to resubmit their present site plans within four years of receiving a licence under the Aggregates Act. These new plans should include more details on rehabilitation such as proposed contours, grading techniques, topsoil replacements, seeding mixtures and methods as well as post rehabilitation management; all of which the operator will be required to adhere to. The new Act also allows the Minister to require a licensee to amend his site plans. The result of these provisions should be a site plan that more accurately reflects the realities of the operation and is more useful to the operator, Ministry staff and the general public.

Abandoned Pit Fund

In much of Ontario there are literally hundreds of abandoned pits that were operated prior to the P.Q.C.A. These sites were never licenced. These sites have done little to improve the reputation of the aggregate industry in the eyes of the general public. The Aggregates Act will establish an Abandoned Pit Fund and allow the Ministry to gradually rehabilitate these sites in co-operation with the landowners. The money will be set aside from a portion of the per tonne licence fee collected under the Act and can be used for pre-program surveys or studies and the rehabilitation of abandoned pits and quarries. This program will be implemented in close consultation with local governments and landowners.

Enforcement

Any regulation or piece of legislation is effective only if it is enforced. This is equally true for the Aggregates Act as it pertains to rehabilitation and to a large extent its effectiveness will depend on the ability of staff to enforce the new legislation. The improvements in wording that were previously discussed will go a long way towards making the Aggregates Act more enforceable than its predecessor. Improved clarity and closed loopholes will facilitate legal action when other methods of persuation have failed. In addition the Aggregates Act includes the following provisions that will make it more enforceable. It should also be noted that while the Act gives the Ministry increased powers of enforcement it also provides the licensee with increased opportunities for appeal.

1) The Minister may suspend a licence for any contravention of the Act, Regulations, site plans or licence conditions.

This will provide an effective mechanism for dealing with infractions without the delays and frustrations of going through the courts. Under the P.Q.C.A. suspension was only allowed where there was "an immediate threat to the public".

2) The situations where the Minister may apply to a court for a restraining order (court order) have been expanded to include contraventions of the site plan or licence conditions instead of only the Act and regulations.

3) A minimum fine of $500.00 has been added to assist the courts in sentencing following a conviction. In the past small fines provided a minimal deterrent.

4) The Act gives the courts the authority to make orders to obtain compliance following a conviction. This would be in addition to imposing a fine and will help rectify infractions. In the past obtaining a conviction and fine did not necessarily ensure the infraction would be rectified.

5) Administratively it will be easier to take legal action, under the Aggregates Act since the Minister's permission will not be required before legal action is initiated.

CONCLUSION

Seventeen years of aggregate resource management under the Pits and Quarries Control Act has resulted in significant improvements in the quantity and quality of rehabilitation across the province. However, experience with the legislation has also brought to light inadequacies, and the commitment to progressive rehabilitation has not been as widespread as was hoped. The proposed Aggregates Act should resolve all of the problems with the present legislation and will open the door to further improvements in the rehabilitation of the province's pits and quarries. It is hoped that better rehabilitation in the future will increase the acceptability of the industry and facilitate the supply of an essential natural resource.

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REVEGETATION EN MILIEU NORDIQUE

REVEGETATION IN THE NORDIC ENVIRONMENT

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Résumé:

La réalisation d'ouvrages en zones bioclimatiques arctique et hémiarctique entraîne souvent la perturbation ou la destruction d'un couvert végétal qui a mis plusieurs années à croître et qui présente une capacité de regénération naturelle très limitée. Ainsi, tout au cours du long et fragile processus de recolonisation des sites perturbés, les sols sont soumis à des phénomènes d'érosion éolienne et hydrique et, à des modifications du pergélisol qui sont susceptibles d'affecter l'intégrité des ouvrages, de provoquer des nuisances pour la population ou de prolonger la dégradation visuelle du milieu.

Pour contrer ces inconvénients, des recherches ont été menées sous la commandite du ministère des Transports du Québec et de l'Administration régionale Kativik pour identifier des espèces végétales et des techniques de revégétation répondant aux conditions difficiles du milieu nordique.

Ainsi, de l'été 1985 à l'hiver 1987-1988, vingt-cinq (25) espèces herbacées, ornementales ou arbustives ont été expérimentées dans quatre communautés inuit du Québec situées entre de 55^{e} et le 61^{e} parallèle. Différentes techniques d'ensemencement, de repiquage et de forçage ont également été mises à l'essai.

Les différentes expérimentations ont permis la mise au point d'un mélange de semences commerciales et de techniques de forçage qui assurent l'implantation et la survie d'un couvert végétal herbacé sur un substrat relativement stérile, grossier, à drainage rapide et contenant peu de matière organique et ce, dans des conditions de croissance végétative particulièrement rigoureuses.

Les recherches portaient également sur le repiquage et l'ensemencement de quelques espèces indigènes. Plus particulièrement, l'élyme des sables dont les graines ont été récoltées sur place et ensemencées. Cette espèce a fait preuve d'une capacité remarquable d'implantation dans les sables des dunes caractérisant les rivages marins de la baie d'Hudson.

Si les résultats de ces recherches ne permettent pas de statuer sur le succès à long terme de l'implantation du mélange commercial ni sur le remplacement des espèces introduites par la végétation indigène, ils constituent toutefois des acquis suffisamment éloquents pour justifier des projets-pilotes plus importants et laissent entrevoir des applications nombreuses pour la protection des ouvrages réalisés en zone de pergélisol et pour l'aménagement des villages nordiques.

Abstract:

Development of projects in arctic and subarctic bioclimatic regions often entail disturbance or destruction of surface vegetation which has taken many years to grow and which does not naturally regenerate easily. In addition, throughout the long and delicate process of colonizing disturbed sites, the ground is subjected to wind and water erosion as well as alteration of the permafrost, all of which can affect the solidity of project structures, cause problems with local populations or futher disfigure the environment.

To deal with these problems, the Quebec Ministry of Transport and Kativik Regional Administration sponsored research to determine vegetation species and revegetation techniques suitable for the harsh conditions of northern environments.

From the summer 1985 to the winter 1987-88, twenty-five herbaceous, ornamental and shrub species were tested in four Inuit communities in Quebec between the 55th and 61st parallel. Various techniques for seeding, planting out and forcing were also tested.

On the basis of the findings of the various experiments, it was possible to develop a mix of commercial seeds and certain forcing techniques which can guarantee establishment and survival of a herbaceous cover on a relatively sterile, rough, very well-drained substrate in a climate where conditions for vegetation growth are particularly harsh.

Experiments with planting out and seeding of certain indigenous species were also conducted; Sea Lime-

grass seeds were harvested on the spot, for example, and then sowed. This species has a remarkable capacity for establishment in the sand dunes along the coast of Hudson Bay.

Although it is not possible on the basis of the research described to date to hail successfull long-term establishment of a commercial mix or the replacement of species introduced by indigenous vegetation, the research project has certainly been sufficiently successful to warrant undertaking of larger-scale pilot projects and to suggest numerous possiblities for the protection of development structures in permafrost areas and for the development and landscaping of northern villages.

INTRODUCTION

La réalisation d'ouvrages en zones bioclimatiques arctique et hémiarctique entraîne souvent la perturbation ou la destruction d'un couvert végétal qui a mis plusieurs années à croître et qui présente une capacité de regénération naturelle très limitée. Ainsi, tout au cours du long et fragile processus de recolonisation des sites perturbés, les sols sont soumis à des phénomènes d'érosion éolienne et hydrique et à des modifications du pergélisol qui sont susceptibles d'affecter l'intégrité des ouvrages, de provoquer des nuisances pour la population ou de prolonger la dégradation du milieu.

Dans le cadre de son programme d'amélioration des infrastructures aéroportuaires dans onze communautés du Nord du Québec, le ministère des Transports du Québec projette de renaturaliser certaines aires touchées par les travaux de construction. Pour ce faire, le ministère a mis sur pied un projet de recherche permettant d'identifier des espèces végétales et des techniques de revégétation qui puissent mener à l'implantation d'un couvert végétal en milieux arctique et hémiarctique.

Au cours de l'expérimentation qui s'est échelonnée sur deux ans, l'Administration Régionale Kativik a également mis en oeuvre un projet de recherche, ce qui a permis d'accroître le nombre de sites et de diversifier les conditions d'expérimentation. Les deux projets de recherches réalisés par phases, de l'éte 1985 à l'automne 1987 ont été confiés au Groupe Conseil Entraco Inc.

Les différentes expérimentations ont permis la mise au point d'un mélange de semences commerciales et de techniques de forçage qui assurent l'implantation et la survie d'un couvert végétal herbacé sur un substrat relativement stérile, grossier, à drainage rapide et contenant peu de matière organique et ce, dans des conditions de croissance végétative particulièrement rigoureuses.

Le projet de recherche a également permis d'élaborer sur l'utilisation, par repiquage ou ensemencement, d'espèces indigènes aptes à revégéter des sites dégradés.

1. CADRE BIOCLIMATIQUE DE L'ETUDE

Les essais ont été réalisés dans les communautés de Kangiqsujuaq, Inukjuak, Umiujaq et Kuujjuarapik. Ces dernières se situent entre les latitudes 54° et 62° dans les zones bioclimatiques arctique et hémiarctique du Québec. La figure 1 montre la localisation des municipalités qui ont fait l'objet de l'implantation d'un site expérimental tandis que le tableau 1 fournit des données bioclimatiques des secteurs à l'étude.

Notons que les conditions de croissance de la végétation diffèrent selon les endroits. Kangiqsujuaq bénéficie de 200

FIGURE 1: CARTE DE LOCALISATION DES SECTEURS A L'ETUDE (*)

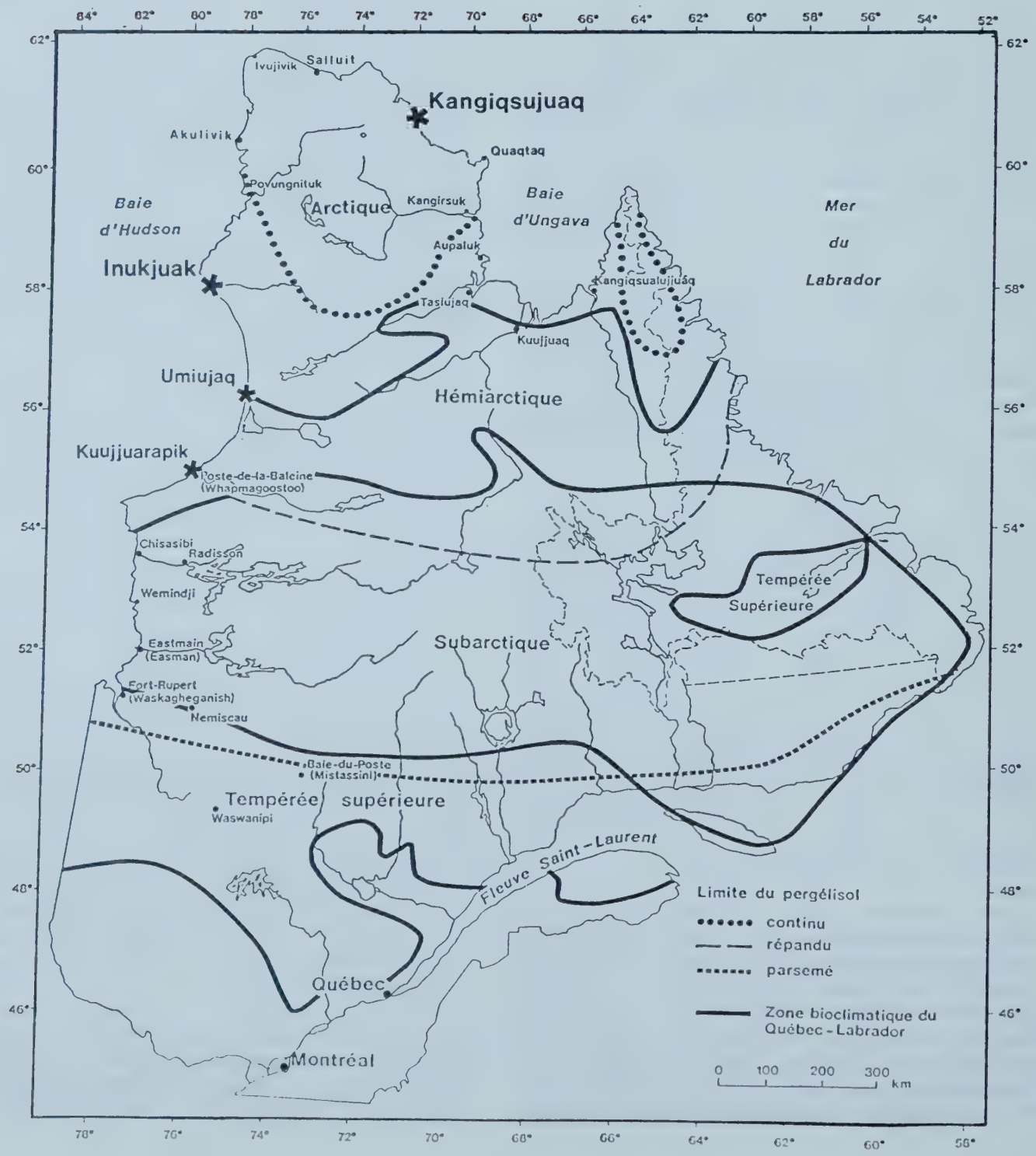


TABLEAU 1: DONNEES BIOCLIMATIQUES DES SECTEURS A L'ETUDE

	KANGIQSUJUAQ	INUKJUAQ	KUUJJUARAPIK	UMIUJAQ
Température moyenne annuelle[2]	-7,0°C	-6,7°C	-4,3°C	-5,5°C
Température moyenne de juillet[1,4]	7,0°C	8,9°C	-	-
Température moyenne d'août[4]	-	8,6°C	-	-
Nombre annuel de degré-jours de croissance (où T° 5,6°C)[1]	200	400	800	800
Durée annuelle moyenne de la saison de croissance[2]	40 jours	80 jours	120 jours	100 jours
Date moyenne du début de la saison de croissance[3]	30-6	20-6	-	-
Date moyenne de la fin de la saison de croissaance[3]	31-8	20-9	-	-
Durée annuelle moyenne de la période sans gel[2]	20 jours	60 jours	80 jours	80 jours
Date moyenne de la dernière gelée du printemps[1]	30-6	30-6	15-6	14-6
Date moyenne de la première gelée d'automne[1]	1-8	15-9	15-9	24-9
Précipitations totales moyennes annuelles[2]	400mm	500mm	680mm	526mm
Vent horaire moyen annuel[1]	20km/h	20km/h	20km/h	20km/h
Peréglisol	continu	dis-continu	dis-continu	dis-continu

Sources: 1 - GAGNON & FERLAND, 1967
2 - OPDQ, 1983
3 - WILSON, 1971
4 - SEBJ, 1978

degrés-jours de croissance et se situe en zone de pergélisol continu alors que Kuujjuarapik profite de 800 degrés-jours de croissance et est en zone de pergélisol discontinu. Des écarts importants se retrouvent aussi au niveau de la durée de la saison de croissance, de la période sans gel ou des précipitations moyennes annuelles.

2. PROTOCOLE DE RECHERCHE

Le protocole de recherche s'est réalisé en trois phases distinctes en optimisant à chaque phase le choix des espèces végétales ou des techniques de revégétation.

A l'automne 1985 (28 août), douze espèces de semences commerciales ont été ensemencées avec ou sans paillis protecteur à Kangiqsujuaq sur trois stations expérimentales regroupant 155 quadrats de 1 mètre par 1 mètre dans des conditions de sol et d'humidité différentes. Ce sont les variétés suivantes:

1. Agrostide blanche
2. Agropyre accrêté
3. Fétuque rouge traçante
4. Fétuque durette durar
5. Fléole des prés
6. Pâturin du Canada
7. Pâturin des prés Nugget
8. Puccinellie à fleurs distantes
9. Trèfle blanc à pousse basse
10. Trèfle hybride (alsike)
11. Trèfle d'odeur jaune
12. Lotier corniculé

Le but de cette première expérimentation était d'identifier un groupe de semences commerciales qui pourraient être utilisées en mélange pour la revégétation et de statuer sur la nécessité d'utiliser ou non un agent protecteur pour assurer l'implantation de ces végétaux.

La première station de 96 quadrats est située sur du gravier grossier exempt de matière organique décapée avec une pente variant de 25° à 40° exposée vers l'est et dont le drainage passe d'excessif en haut de la pente à imparfait en bas. La deuxième station expérimentale de 42 quadrats est implantée sur un sable grossier exempt de matière organique avec une pente variant de 0° à 10° exposée vers le nord et dont le drainage est imparfait. La troisième station se situe sur un loam sableux riche en matière organique où la pente est nulle et la nappe phréatique près de la surface du sol.

Quant à l'ensemencement, il a été effectué manuellement à la volée à un taux équivalent à 150kg par hectare puis les semences ont été légèrement enfouies avec un râteau.

Les essais comprenaient également la plantation de quelques 60 jeunes pousses d'aulne crispé inoculées avec le mycorhize "Frankia". Finalement, une trentaine de touffes d'élyme des sables prélevées sur place ont été repiquées et se répatissent à chacune des stations.

Cette première phase a permis de sélectionner quelques espèces commerciales qui réussissent à croître dans les milieux arctiques.

La deuxième phase s'est traduite par l'implantation, en date du 16 juillet 1988, d'une quatrième station expérimentale à Kangiqsujuaq comprenant 24 quadrats de 1 mètre par 2 mètres chacun. A partir des résultats obtenus au cours de la phase 1, deux mélanges de semences commerciales ont été mis à l'essai en combinaison avec différents traitements tels que la fertilisation, l'ajout de fibres cellulosiques (Benovert) et de "Terra-sorb" et finalement la pose de paillis.

Les mélanges de semences commerciales mis à l'essai se décrivent comme suit:

Mélange 1	
Avoine	10%
Agrostide blanche	10%
Fétuque rouge traçante	40%
Pâturin des prés	35%
Trèfle hybride	5%

Mélange 2	
Agrostide blanche	10%
Fétuque durette durar	20%
Fléole des prés	10%
Puccinellie à fl. distantes	10%
Pâturin des prés	45%
Trèfle hybride	5%

Les semis au taux équivalent de 250kg par hectare ont été effectués manuellement, à la volée puis les semences ont été légèrement enfouies au râteau.

Les traitements utilisés sont décrits dans les paragraphes qui suivent.

Fertilisation: deux programmes de fertilisation ont été mis à l'essai. Lepremier programme de fertilisation (F1) se compose d'une partie d'engrais granulaire et d'une autre partie d'engrais à libérationlente (résiné), ce qui assure une disponibilité d'éléments nutritifs pour plus d'une saison de croissance. Le deuxième programme (F2) est composé uniquement d'engrais granulaire qui se libère relativement vite selon le degré d'humidité du sol.

Les caractéristiques de ces fertilisants et les taux d'application se présentent comme suit:

F1: 7-7-7 granulaire au taux de 800kg/ha et 14-14-14 résiné au taux de 400kg/ha

F2: 7-7-7 granulaire au taux de 1 200kg/ha

L'engrais a été répandu manuellement, à la volée, et immédiatement avant l'ensemencement.

Bénovert: cet agent protecteur constitué de papier broyé et teint de couleur verte, maintient théoriquement un bon niveau d'humidité et offre une protection contre l'érosion. Il a été épandu à la surface du sol au taux de 1 400kg/ha en l'appliquant manuellement et en l'arrosant par la suite.

Terra-sorb: ces particules de type colloidales absorbent jusqu'à 1 000 fois leur volume en eau et la restituent graduellement au sol. Leur utilisation dans des sols à drainage excessif vise à maintenir un niveau d'humidité suffisant à la surface du sol pour favoriser la germination et la croissance. Le produit a été mélangé à la semence puis appliqué au taux de 7kg par hectare.

Paillis: le paillis vise à maintenir un certain niveau d'humidité à la surface du sol favorisant ainsi la germination et la croissance. De plus, tout en constituant un apport de matière organique, il assure une protection contre les érosions éolienne et hydrique ainsi qu'une protection hivernale.

Le paillis utilisé est de type "Ero-mat" dont l'épaisseur varie de 10 à 15mm. Il est constitué de paille entrelacée et retenue par un filet synthétique photodégradable. Il se présente en rouleau de 2 mètres de largeur et de 40 mètres de longueur. Il est étendu manuellement et fixé à l'aide de crampons enfoncés dans le sol (1,5 crampons/mètre carré).

La station expérimentale est fortement exposée aux vents et présente un drainage qui varie de bon à excessif. Le sol arable a été décapé mécaniquement afin de

reproduire les conditions de sols que l'on retrouve généralement suite aux travaux de construction, soit: sol fraîchement remanié, pauvre en matière organique, substrat grossier et absence de couvert végétal.

Le substrat se compose de gravier grossier dont la porosité est élevée. La pente du terrain est de l'ordre de 5° avec une exposition en direction sud. Le site est protégé au nord par une falaise d'environ 150 mètres de hauteur. Il est cependant encaissé dans une vallée constituant un corridor préférentiel pour les vents dans l'axe est-ouest.

Une troisième phase à laquelle s'ajoute le projet de recherche commandité par l'Administration Régionale Kativik a permis d'expérimenter deux autres mélanges optimisés de semences commerciales ainsi que l'ensemencement de graines d'élyme des sables. L'implantation de cette troisième phase s'est déroulée du 29 septembre au 8 octobre 1986 à Kangiqsujuaq, Inukjuak, Umiujaq et Kuujjuarapik et comporte l'ensemencement de 75 quadrats de 2 mètres carrés et le repiquage d'une vingtaine de touffes d'élyme des sables.

Les variétés expérimentées en semis pur ou en mélange se décrivent comme suit:
- Semences commerciales

Mélange 8	
Agrostide blanche	5%
Fétuque rouge traçante	20%
Fétuque durette durar	45%
Fléole des prés	20%
Lotier corniculé	10%

Mélange 9	
Agrostide blanche	5%
Fétuque durette durar	30%
Fléole des prés	40%
Pâturin des prés	10%
Puccinellie à fl. distantes	10%

De façon particulière, un nouvel élément a été ajouté à Umiujaq et à Kuujjuarapik soit l'ensemencement d'élyme des sables dont les graines avaient été résoltées à Kuujjuarapik le 29 septembre 1966. En effet, l'élyme des sables présente presque partout sur les dunes de sable des rivages marins nordiques, offre un intérêt certain pour la revégétation de ce type de sol particulièrement éolisable.

Comme pour les essais précédents, les semis au taux équivalant de 250kg/ha ont été effectués manuellement à la volée puis les semences ont été légèrement enfouies au râteau.

Les traitements mis à l'essai sont sensiblement les mêmes que ceux décrits précédemment, soit la fertilisation, l'ajout de "bénovert" et de "terra-sorb" et la pose de paillis. Cependant, compte tenu que l'expérience a eu lieu à l'automne, l'engrais granulaire a été remplacé par du 5-20-20 à teneur réduite en azote afin d'éviter un aoûtement tardif et une faible résistance aux conditions hivernales.

A Kangiqsujuaq, la station expérimentale mise en place se situe au même endroit que celle de la deuxième phase et possède les mêmes caractéristiques que celle-ci.

A Inukjuak, le substrat de la station expérimentale est constitué de sable grossier et de gravier mince (15cm) reposant sur de l'argile. Le terrain est légèrement accidenté et la pente générale est nulle. La nappe phréatique est près de la surface et l'humidité varie de faible à très élevée. Des buttes de gravier bordent le site expérimental si bien que celui-ci est relativement bien protégé des vents.

A Inukjuak et à Kangiqsujuaq, les conditions étaient peu favorables à la mise en place des essais. Ainsi, le sol était gelé, la neige commençait à s'accumuler et des vents balayaient la région.

A Umiujaq, le site expérimental a été mis en place les 2 et 3 octobre 1986 sur une terrasse de sable éolisable décapé surplombant un profond ravin. Le substrat est composé de sable fin à moyen relativement homogène et exempt de matière organique. L'humidité du sol est très faible et le drainage excessif. Le terrain présente une pente variant de nulle à 2%.

Pour ce qui et de Kuujjuarapik, les conditions de sol sont semblables à celles d'Umiujuaq, la station expérimentale se situant sur une dune de sable caractéristique de la côte est de la baie d'Hudson.

Le site expérimental est exposé au sud-est avec une pente de 20%. L'humidité y est faible, le drainage est excessif et l'exposition aux vents varie de moyenne à forte. Le substrat est constitué de sable fin à moyen relativement homogène et sans matière organique.

RESULTATS, ANALYSES ET DISCUSSIONS

Méthodologie d'observation

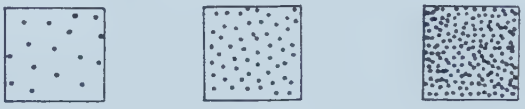
La figure 2 présente la méthodologie utilisée pour évaluer le niveau de croissance des végétaux implantés. L'évaluation est basée sur trois critères, soit:

- la densité du couvert végétal
- le recouvrement du quadrat
- la hauteur moyenne des tiges

D'autres aspects comme l'érosion de surface, le transport des graines, la présence de tiges séchées et de tiges brunies ont été relevés ponctuellement et sont particuliers à quelques quadrats.

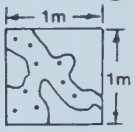
FIGURE 2: METHODOLOGIE D'EVALUATION DU NIVEAU DE CROISSANCE DES ENSEMENCEMENTS

- Densité: Nombre de tiges (ou la "concentration" de tiges) d'une surface couverte.



faible moyenne élevée

- Recouvrement: Proportion de surface couverte par les tiges à l'intérieur d'unquadrat



catégorie: - 10%; de 10 à 25%; de 25 à 50%;+ 50%.

- Hauteur: Hauteur moyenne des tiges en millimètre mesure de 3 à 5 fois sur chaque placette et pour chaque espèce à partir du niveau du sol.

La densité du couvert végétal reflète le nombre de tiges présentes dans la partie du quadrat qui fait l'objet d'un recouvrement quelconque. A titre d'ordre de grandeur, nous avons défini comme densité élevée un nombre de tiges supérieur à environ 100/dm^2 et comme densité faible un nombre inférieur à 5/dm^2. Une densité située entre ces deux limites est considérée comme moyenne.

Le recouvrement représente la proportion de surface couverte à l'intérieur d'un quadrat que nous avons établi en 4 catégories, soit moins de 10%, de 10 à 25%, de 25 à 50% et plus de 50%.

Afin de faciliter l'analyse des résultats, les variables "densité"

TABLEAU 2: TABLEAU DE DETERMINATION DE L'INDICE DENSITE-RECOUVREMENT

DENSITE	RECOUVREMENT			
	- de 10%	10 à 25%	25% à 50%	+ de 50%
Faible	1	2	4	7
Moyenne	3	5	8	10
Elevée	6	9	11	12

Note: Nous avons attribué un indice de 0 lorsque la densité et le recouvrement sont nuls ou ne comportent que quelques tiges.

et "recouvrement" sont combinées en une variable numérique sous la forme d'un indice densité-recouvrement. Une valeur de cet indice est attribuée à chacun des quadrats selon la grille d'équivalence présentée au tableau 2. Cet indice associé à la hauteur des tiges permet de représenter les résultats sous une forme synthétisée et rapidement consultable. La hauteur moyenne des espèces a été évaluée en mesurant la partie aérienne des tiges de 3 à 5 fois sur chaque quadrat.

Résultats et analyse

1. Première phase: semis pur et aulne crispé

Rappelons que la première phase se traduit par l'ensemencement en semis pur de 12 espèces avec ou sans paillis protecteur et la plantation de plants d'aulne crispé.

Pour les fins de présentation, nous avons divisé les résultats selon deux milieux distincts, soit: milieu sec et milieu humide.

Les tableaux 3 et 4 montrent les indices densité-recouvrement et les hauteurs obtenus dans les deux milieux.

De façon générale, retenons que la croissance mesurée en 1986 est légèrement supérieure en milieu humide par rapport au milieu sec et ce, pour la majorité des variétés. En effet, pour les 36 données des relevés de 1986, l'indice densité-recouvrement donne une moyenne de 4,39 ± 3,84 en milieu sec et de 9,06 ± 2,96 en milieu humide. La hauteur fournit une moyenne de 13,94 ± 13,78 en milieu sec et de 21,14 ± 14,98 en milieu humide. La deuxième saison (1987) révèle que seule la fétuque rouge traçante, la fétuque durette durar ainsi que le lotier corniculé (ce dernier en milieu humide seulement) montrent une résistance aux conditions hibernales et fournissent un niveau de croissance acceptable.

A cet effet, nous considérons qu'un indice densité-recouvrement inférieur à 5 ne représente pas un succès suffisant pour parler d'implantation véritable. Cette situation correspond à une densité moyenne ou faible et à un recouvrement de moins de 25% du quadrat.

De façon plus détaillée, notons que la fléole des prés a montré une rapidité d'implantation dès l'automne 1985. Ce qui lui confère une qualité de plante stabilisatrice à très court terme.

TABLEAU 3: INDICE DENSITE-RECOUVREMENT ET HAUTEUR, KANGIQSUJUAQ: MILIEU SEC

Conditions: sol: gravier et sable grossier
pente: banc E: 25 à 40°
drainage: bon à excessif
Date d'ensemencement: 85-08-28

VARIETE	NOMBRE DE QUADRATS	DATES DES RELEVES			
		86-07-17	86-08-04	86-08-19	87-08-26
1-Agrostide blanche	4 à 6	2[1](4)[2]	5 (9)**	1 (4)	0 (0)
2-Agropyre accrêté	4 à 6	3 (48)	7 (45)**	8 (33)**	1 (11)**
3-Fétuque rouge traçante	4 à 6	10 (31)	10 (41)	10 (30)	6 (23)**
4-Fétuque durette durar	4 à 6	9 (28)	12 (34)	12 (24)	5 (25)**
5-Fléole des prés	4 à 6	10 (24)	10 (27)**	9 (15)**	0 (0)**
6-Pâturin du Canada	4 à 6	1 (2)	1 (10)**	1 (6)**	0 (0)
7-Pâturin des prés	4 à 6	2 (3)	2 (6)**	2 (8)**	0 (0)
8-Puccinellie à fleurs distantes	4 à 6	2 (4)	5 (12)** *	1 (9)** *	0 (0)
9-Trèfle blanc	4 à 6	1 (2)	1 (2)**	1 (3)	0 (0)
10-Trèfle hybride	4 à 6	4 (5)	1 (4)**	1 (4)	0 (0)
11-Trèfle d'odeur	4 à 6	0 (0)	1 (2)	1 (5)	0 (0)
12-Lotier corniculé	4 à 6	3 (3)	3 (6)	6 (9)	0 (0)
Total	48 à 72				

* Majorité de tiges brunies
** Présence de tiges sèches (mortes)
1 Moyenne des indices densité-recouvrement arrondie à l'unité
2 Moyenne des hauteurs en mm

TABLEAU 4: INDICE DENSITE-RECOUVREMENT ET HAUTEUR, KANGIQSUJUAQ: MILIEU HUMIDE

Conditions: sol: gravier et sol organique
pente: banc E: 25 à 40°
banc F: 0 à 10°
drainage: moyen mauvais
Date d'ensemencement: 85-08-28

VARIETE	NOMBRE DE QUADRATS	DATES DES RELEVES			
		86-07-17	86-08-04	86-08-19	87-08-26
1-Agrostide blanche	4 à 8	11[1](14)[2]	12 (27)	12 (27)	1 (5)**
2-Agropyre accrêté	4 à 8	5 (24)	12 (52)	9 (53)	1 (15)**
3-Fétuque rouge traçante	4 à 8	11 (30)	11 (48)	12 (56)	10 (35)**
4-Fétuque durette durar	4 à 8	7 (24)	10 (43)	9 (33)	11 (33)
5-Fléole des prés	4 à 8	11 (21)	11 (33)	11 (42)**	2 (9)**
6-Pâturin du Canada	4 à 8	8 (9)	10 (14)	9 (18)	1 (4)**
7-Pâturin des prés	4 à 8	7 (16)	12 (24)	10 (16)	4 (4)**
8-Puccinellie à fleurs distantes	4 à 8	10 (13)	10 (21)	10 (18)*	3 (3)
9-Trèfle blanc	4 à 8	5 (8)	4 (6)	4 (10)	0 (0)
10-Trèfle hybride	3 à 5	10 (5)	11 (5)	11 (9)	1 (3)
11-Trèfle d'odeur	2 à 4	2 (9)	4 (11)	2 (4)	0 (0)
12-Lotier corniculé	3	9 (5)	12 (7)	12 (6)	10 (5)
Total	42 à 84				

* Majorité de tiges brunies
** Présence de tiges sèches (mortes)
1 Moyenne des indices densité-recouvrement arrondie à l'unité
2 Moyenne des hauteurs en mm

Les autres espèces n'ont pas démontré leur capacité à s'implanter dans des conditions de milieu arctique. Pour ce qui est des plants d'aulne crispé, ils n'ont pu s'implanter et croître dans les conditions rencontrées à Kangiqsujuaq.

2. Deuxième phase: mélanges et traitements

Signalons que la deuxième phase consiste à expérimenter deux types de mélanges de semences commerciales (mélanges 1 et 2) ainsi que divers traitements aptes à favoriser l'implantation des espèces ensemencées.

Mélanges 1 et 2:

Le tableau 5 présente les résultats obtenus à Kangiqsujuaq lors de quatre relevés dont trois en 1986 et l'autre en 1987.

Sauf pour le relevé du 86 08 04, la hauteur moyenne a été calculée en pondérant la hauteur de chacune des espèces qui ont levé par leur pourcentage dans la composition du mélange et en la ramenant à 100%. L'exemple pour le cas du mélange 1 et du traitement PF1 en date du 86 08 19 nous donne ce qui suit:

Exemple:

$$\frac{(30\text{mm} \times 40\%)+(80\text{mm} \times 10\%)+(30\text{mm} \times 10\%)}{60\%} = 38\text{mm}$$

Les observations révèlent que la fétuque rouge et la fétuque durette durar sont présentes de façon constante dans la plupart des quadrats. De plus, ce sont ces espèces qui sont les plus abondantes. Nous retrouvons également l'agrostide blanche et le trèfle hybride dans 60% des quadrats.

Pour ce qui est des indices densité-recouvrement et des hauteurs, les quadrats-témoins des mélanges 1 et 2 sont comparables et il ressort qu'aucun de ceux-ci ne résiste aux conditions hivernales sans traitement préalable.

De façon générale, si on considère les 48 données de chacun des mélanges, ceux-ci présentent des indices densité-recouvrement comparables. Les hauteurs généralement plus élevées du mélange 1 sont attribuables à la présence de l'avoine utilisée comme plante-abri annuelle.

En ce qui concerne les traitements, nous présentons ci-après l'analyse des résultats en fonction de chacun des traitements expérimentés. Notons que dans certains cas, nous considérerons aussi les quelques résultats obtenus sur les essais de la troisième phase afin d'éviter de revenir sur le sujet lors de cette dernière analyse.

Bénovert (mulch): cet agent protecteur appliqué en traitement simple n'a eu que peu d'effet sur la germination ou la croissance par rapport au témoin.

En traitement combiné (PF1 vs PMF1 ou F vs MF), on obtient un effet tantôt positif, tantôt négatif et aucune amélioration de la croissance ne peut par conséquent être attribuée à cet agent par rapport aux différents quadrats-témoins.

Terra-sorb: les résultats montrent qu'en traitement simple, il a un effet positif sur la croissance la première année par rapport au témoin (indice densité--recouvrement: 11 et 12 vs 1 et 4). Cependant, cette santé apparente n'a pas assuré pour autant aux mélanges une résistance à l'hiver (relevé87 08 27). En traitement combiné, on ne peut pas isoler son effet, celui-ci étant trop marginal.

TABLEAU 5: INDICE DENSITE-RECOUVREMENT ET HAUTEUR, KANGIQSUJUAQ: MELANGE 1 ET 2, BANC E - 1986

MELANGES ET TRAITEMENTS	DATE DES RELEVES			
	86-08-04	86-08-19	86-10-08	87-08-27
Mélange # 1				
Témoin	1[1](17)[2]	4 (15)	4 (38)	0 (0)
Traitements simples				
Bénovert (M)	4 (30)	1 (18)	4 (25)	0 (0)
Terra-sorb (S)	12 (10)	12 (33)	11 (42)	0 (0)
Paillis (P)	11 (33)	11 (21)	8 (19)	0 (0)
Fertilisation (F1)	12 (31)	12 (44)	12 (39)	12 (66)
Fertilisation (F2)	5 (34)	11 (30)	11 (45)	4 (44)
Traitements combinés				
PF1	12 (27)	12 (38)	12 (45)	12 (100)
PF2	12 (18)	11 (68)	12 (62)	12 (63)
PGF1	12 (78)	12 (24)	12 (65)	12 (82)
PMF1	11 (48)	11 (23)	11 (36)	12 (75)
PGSF1	11 (49)	12 (35)	12 (60)	12 (78)
Mélange # 2				
Témoin	1 (12)	4 (16)	4 (27)	0 (0)
Traitements simples				
Bénovert (M)	1 (12)	4 (21)	11 (26)	0 (0)
Terra-sorb (S)	12 (28)	12 (15)	11 (18)	0 (0)
Paillis (P)	12 (12)	8 (24)	8 (27)	0 (0)
Fertilisation (F1)	12 (35)	12 (20)	12 (27)	10 (57)
Fertilisation (F2)	11 (12)	12 (30)	12 (30)	4 (26)
Traitements combinés				
PF1	12 (13)	12 (21)	12 (21)	12 (90)
PF2	12 (13)	12 (30)	12 (47)	12 (53)
PGF1	12 (28)	12 (22)	12 (36)	12 (70)
PMF1	11 (36)	11 (20)	11 (26)	12 (41)
PGSF1	12 (28)	12 (34)	12 (29)	12 (54)

1 Indice densité-recouvrement
2 Moyenne pondérée des hauteurs en mm

Fertilisation: le résultats révèlent la supériorité du programme F1 sur le programme F2. Les hauts taux d'application de ce dernier (1 200kg/ha) ont possiblement eu un effet toxique qui s'est fait sentir sur la résistance à l'hiver. De plus, on note clairement l'effet positif de l'engrais libération lentela deuxième année de croisance (F1 vs F2).

En traitement simple ou en traitement combiné, la fertilisation assure à elle seule, la résistance à un premier hiver pour les mélanges 1 et 2 quel que soit le traitement avec lequel il est combiné. Par ailleurs, c'est en combinaison avec le paillis que ce traitement est le plus prometteur. Ainsi, pour tous les quadrats où F1 est présent en 1987, on obtient des indices densité-recouvrement supérieurs 10 (généralement de 12) et des hauteurs variant de 41mm à 100mm pour une moyenne de 71,3mm ± 16,7 (n=10).

TABLEAU 6: HAUTEUR MOYENNE DES TIGES TEMOIN VS PAILLIS ET FERTILISANT

	Traitement			
	Témoin (T)	Paillis (P)	Fertilisant (F1)	Paillis et fertilisant (PF1)
Mélange 1	17,5±13,5* n=4	18,3±11,8 n=4	45,0±13,0 n=4	52,5±28,2 n=4
Mélange 2	13,8±9,7 n=4	15,8±10,7 n=4	34,8±13,9 n=4	36,3±31,2 n=4
Total	15,6±11,9 n=8	17,0±11,3 n=8	39,9±14,4 n=8	44,4±30,8 n=8

* Hauteur moyenne de la partie aérienne (mm) ± écart-type

TABLEAU 7: HAUTEUR MOYENNE DES TIGES TEMOINS VS PAILLIS

	Date des relevés			
	86 07 17	86 08 04	86 08 19	87 08 26
Témoin (T)	13,7±8,9 n=6	19,0±12,5 n=6	20,6±10,5 n=5	9,9±10,3 n=6
Paillis (P)	20,5±13,2 n=6	32,8±19,5 n=6	50,6±18,4 n=5	10,6±14,1 n=6

D'autre part, le tableau 6 suivant fournit la hauteur moyenne des tiges (témoin vs paillis et fertilisant) pour les quatre relevés effectués sur les mélanges 1 et 2.

On constate que la fertilisation a eu un effet marqué sur la croissance pour tous les mélanges. La hauteur moyenne obtenue est de 2,6 fois supérieure à celle du témoin (39,9mm vs 15,6mm). On obtient les mêmes tendances si on considère chacun des mélanges séparément (45,0mm vs 17,5mm et 34,8mm vs 13,8mm).

En combinaison avec le paillis, on obtient un effet cumulé de croissance de 2,8 fois supérieur au témoin (44,4mm vs 15,6mm). Après pondération, le fertilisant intervient donc pour 70% dans le succès de la croissance des végétaux implantés alors que le paillis occupe une part de 30%. Cependant, la part de ce dernier prendrait une toute autre importance si on se situait dans des conditions particulières d'érosion éolienne ou hydrique ou encore de grande exposition au froid.

Paillis: en traitement simple, le paillis favorise nettement la croissance durant la premire année par rapport au témoin. Il n'assure cependant pas la survie des espèces après un premier hiver.

C'est en combinaison avec le fertilisant qu'il est le plus efficace.

Le tableau 6 révèle en effet que le paillis favorise la croissance des mélanges 1 et 2 selon un facteur de 1,1 par rapport au témoin alors que ce facteur devient 2,8 en combinaison avec le fertilisant.

Le tableau 7 présente les hauteurs moyennes des tiges de semences commerciales en semis pur implantées à l'automne 1985 à Kangiqsujuaq lors de la phase 1 (témoin vs paillis). Ces moyennes regroupent un ensemble de 35 à 53 quadrats-témoins contre 21 à 27 quadrats avec paillis.

Si l'on exclut les valeurs de la deuxième année (87 08 26), on conclut que le paillis a eu un effet positif sur la croissance, les quadrats avec paillis montrant une hauteur plus importante que les témoins. A nouveau, pour la deuxième année, on constate la faiblesse du paillis à assurer la survie des espèces après un premier hiver.

3. Troisième phase: mélanges et espèces indigènes

Rappelons que la troisième phase consiste à expérimenter les mélanges 8 et 9 en combinaison avec divers traitements ainsi que l'élyme des sables en semis et en repiquage.

Mélanges 8 et 9:

Les mélanges 8 et 9 représentent une optimisation de la composition d'un mélange couvre-sol suite aux essais précédents.

Le tableau 8 présente les résultats obtenus à Kangiqsujuaq et Inukjuak les 27 et 30 août 1986 pour les mélanges 8 et 9 et l'élyme des sables.

En ce qui concerne les espèces présentes, les résultats quoique peu nombreux révèlent que la fétuque rouge traçante et/ou la fétuque durette durar sont toujours présentes dans les quadrats des mélanges 8 ou 9. La fléole des prés et l'avoine sont présentes dans 80% des quadrats. Le lotier corniculé se révèle également dans 9 quadrats sur 10 mais sa hauteur est relativement faible (5-10mm).

Si on considère les indices densité-recouvrement et les hauteurs obtenus après une première saison de végétation à Inukjuak, les résultats sont intéressants puisqu'on obtient généralement des indices densité-recouvrement de 8 et plus et des hauteurs variant de 18 à 94mm.

Les faibles résultats obtenus à Kangiqsujuaq s'expliquent outre l'effet mineur d'un sol plus sec, par le fait qu'une bonne partie des semences ont été emportées par le vent sans compter que le sol gelé a empêché d'enfouir les graines immédiatement.

A Umiujaq et à Kuujjuarapik, aucun des mélanges 8 et 9 n'a réussi à croître et à s'implanter dans les sables éolisables sans la protection d'un paillis et ce, probablement en partie à cause du transport des semences par le vent. Le paillis, avec la protection qu'il assure, a permis la pousse de quelques tiges et tout au plus un recouvrement de 25 à 50% selon une densité faible.

A notre avis, il y a tout lieu de croire que la fétuque rouge et la fétuque durette durar réussiraient à croître et à donner une couverture végétale à court terme dans les sables éolisables. Cependant, seul le recouvrement avec une membrane protectrice de l'ensemble de la dune à revégéter permettrait d'utiliser des mélanges de semences commerciales

TALBEAU 8: INDICE DENSITE-RECOUVREMENT ET HAUTEUR KANGIQSUJUAQ ET INUKJUAK

MELANGES ET VARIETES	KANGIQSUJUAQ	INUKJUAK				
	Témoin	Témoin	F*	MF	SF	MSF
Mlange 8	1[1](21)[2]	12(23)	12(23)	12(32)	-	-
9	1(9)	8(20)	12(23)	12(18)	8(22)	8(20)
Elyme des sables	-	4(45)	8(65)	-	-	-

1 Indice densité-recouvrement
2 Moyenne pondérée des hauteurs en mm

non-adaptées à la dynamique de ces sols. En effet, le risque de transport des graines avec le sable est très élevé sans compter la faible résistance des espèces commerciales expérimentées par rapport aux mouvements des sables éolisables (ensablement du collet, blessure aux tiges, déracinement, dessèchement).

Elyme des sables:

L'élyme des sables a été expérimenté en repiquage et en semis.

En repiquage, cette espèce a montré une bonne capacité à s'implanter dans différents types de sol, mais plus particulièrement dans les sables profonds et bien drainés. Le succès de reprise est de l'ordre de 90%. La fertilisation s'est révélée une technique de forçage très bénéfique pour la croissance des plants repiqués.

En semis, l'élyme des sables représente un vif intérêt pour la stabilisation des sables éolisables dans les dunes. En effet, les résultats révèlent que les semences récoltées à l'automne 1986 et ensemencées durant les jours qui suivent ont réussi à s'implanter avec facilité. Même sans paillis, elle croît relativement bien quoique la présence d'une membrane protectrice est souhaitable pour maintenir les semences et le sable en place.

Les quadrats d'élyme des sables fertilisés montrent un avantage certain sur les quadrats non fertilisés quant au recouvrement, la hauteur des tiges et la vigueur des plants au niveau des racines et des feuilles. On a même noté à Kuujjuarapik la formation de rhizomes sur les plantules fertilisées dès la première saison de croissance suivant l'ensemencement.

En ce qui concerne l'opération de récolte des semences d'élyme des sables sur place, nous avons évalué que l'on peut récolter 300kg de graines par hectare et que le rendement de l'opération de récolte incluant la séparation de la graine de l'épi est de 18kg/-personne/jour, ce qui correspond à 540 000 graines/personne/jour. Des expériences similaires réalisées à la Baie James ont donné un rendement de récolte de 575 000 graines/personne/jour (SEBJ, 1984). A noter que la période de maturité des graines varie d'une année et d'une localité à l'autre. Ainsi, les graines d'élyme étaient matures à la fin du mois de septembre à Kuujjuarapik en 1986 alors qu' à certains moments elles

peuvent ne pas atteindre la maturité requise pour la reproduction.

Autres espèces indigènes

Quelques autres graminées indigènes sont largement répandues sur le territoire nordique du Québec et pourraient offrir un potentiel d'utilisation pour la revégétation des sites perturbés en milieu arctique ou hémiarctique. Nos relevés ont permis d'identifier les quelques-unes présentées ci-après:

- Pâturin glauque
- Fétuque rouge
- Arctagrostis à feuilles larges
- Calamagrostis du Canada

Période optimale d'ensemencement

Dans le cadre de ce projet, nous avons expérimenté 3 périodes d'ensemencement, soit: l'automne (fin août à Kangiqsujuaq), le début de l'été (mi-juillet à Kangiqsujuaq) et la fin de l'automne ou le début de l'hiver (début d'octobre à Kangiqsujuaq, Umiujaq et Kuujjuarapik).

Les ensemencements réalisés en été ont donné de moins bons résultats de levée et de résistance à l'hiver parrapport aux ensemencements d'automne compte tenu de la courte saison de végétation. En effet, les végétaux ont eu peu de temps pour germer, croître et accumuler des réserves avant l'hiver et n'ont donc pas résisté aux conditions hivernales.

Par contre, les semences mises en place à la fin de l'automne sont demeurées dormantes tout l'hiver puis elles ont pu profiter de toute la saison de croissance suivante. Les graines ont amorcé leur germination et leur croissance dès la fonte des neiges, au moment où le sol est gorgé d'eau. De plus, un meilleur enracinement a permis de résister aux périodes de sécheresse qui ont pu sévir en été. Un semis d'automne comporte de plus l'avantage d'assurer une bonne adhérence de la semence au sol à cause du poids de la couverture nivale.

La période optimale pour effectuer des ensemencements d'automne variera donc selon la latitude considérée et les conditions climatiques particulières de la saison où les travaux sont projetés. Les conditions micro-climatiques reliées à chaque communauté peuvent aussi affecter cette période. Au Québec, les moments les plus propices se présentent comme suit selon notre expérience:

Latitude	Communautés types	Période optimale de revégétation
55e-57e parallèle	Kuujjuarapik Umiujaq	mi-septembre à mi-octobre
58e-59e parallèle	Inukjuak Kuujjuaq	début septembre à fin septembre
60e-62e parallèle	Quaqtaq Kangiqsujuaq	mi-août à mi-septembre

CONCLUSION ET RECOMMANDATION

Des nombreuses espèces commerciales expérimentées, la fétuque rouge traçante et la fétuque durette durar sont les espèces qui ont montré le meilleur succès de croissance et de résistance aux conditions des milieux arctique et hémiarctique.

De plus, la fléole des prés s'est révéle très rapide d'implantation, ce qui en fait une plante stabilisatrice à court terme. Egalement, l'agrostide blanche et l'avoine, de croissance rapide, sont aptes à jouer le rôle de plantes-abris et à favoriser l'accumulation de neige durant l'hiver.

A partir des différents essais, on peut donc établir un mélange optimal en fonction de la résistance aux conditions du milieu, la rapidité de croissance la première année et le nombre de graines par unité de poids. Le mélange se compose comme suit:

Fétuque rouge traçante	40%
Fétuque durette durar	30%
Fléole ds prés	10%
Agrostide blanche	10%
Avoine	10%

Quant aux traitements, la fertilisation à elle seule s'est révélée le facteur déterminant pour assurer à la fois l'implantation et la survie après un premier hiver des mélanges testés avec une part nette de l'ordre de 70% sur le succès de croissance par rapport au témoin. De plus, c'est en combinaison avec le paillis que les résultats sont les plus prometteurs. Le paillis quant à lui, intervient pour environ 30% du surplus de croissance par rapport au témoin. La fertilisation constitue donc une technique de forçage importante pour des travaux de revégétation en milieu nordique.

A la lumière des résultats, nous sommes en mesure de recommander un programme de fertilisation adapté à un ensemencement d'automne s'élaborant comme suit: un mélange de 50% (en poids) de 5-20-20 granulaire et 50% de 32-0-0 (100% S.C.U.) appliqué au taux de 500kg/ha.

Une recherche plus poussée sur l'effet de la fertilisation dans les mêmes conditions expérimentales permettrait d'optimiser davantage le programme de fertilisation en évaluant entre autres des taux d'application moins élevés.

Dans les sables éolisables, l'élyme des sables surtout en semis, offre un potentiel d'implantation d'un couvert végétal à court et à long terme. Sa facilité d'implantation dans les dunes et plus particulièrement avec une fertilisation adéquate en fait une espèce de choix pour stabiliser ces sols souvent en mouvement.

Les autres espèces n'ont pas démontré une résistance à la dynamique de ce type de sol particulier sans la protection d'un paillis diminuant le mouvement du sable.

Le repiquage d'élyme des sables présente également un intérêt pour établir des écrans de protection ou encore pour un aménagement paysager.

REHABILITATION AT STEETLEY INDUSTRIES LIMITED, QUEENSTON QUARRY, AS AN EXAMPLE OF PUBLIC AND PRIVATE AGENCY CO-OPERATION IN RECLAMATION AND HERITAGE CONSERVATION

LA REHABILITATION AUX INDUSTRIES STEETLEY LTD, LA CARRIERE QUEENSTON EXEMPLE DE COOPERATION ENTRE LES AGENCES PRIVEES ET PUBLIQUES DANS LA REHABILITATION ET LA CONSERVATION DE L'HERITAGE

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Abstract:

The recent donation of land at Queenston Quarries Limited to the Niagara Parks Commission, illustrates recent changes in government reclamation and conservation strategies.

Previous reliance on restrictive legislation is being augmented by more pro-active, less bureaucratic approaches, based on the co-operation of multi-agency networks, innovative approaches to acquisition, and the promotion of private-sector funding and stewardship. At the Queenston Quarry, such an approach has resulted in the timely, effective protection of important natural and cultural resources, through the involvement of the Natural Heritage League, a coalition of public and private agencies committed to resource management and conservation.

The quarry, which is cut into limestones of the Niagara Escarpment near Niagara Falls, dates from early 1800's. It was, at one time, one of the largest cut stone quarries in North America, and is presently a major producer of crushed stone.

On part of the property, archeologically significant remains of early quarry activity lie within areas of century-old naturally regenerated Carolinian Forest species, along the route of the Bruce Trail, at the brow of the Escarpment.

Legislation enacted in the 1960's and 1970's prohibited any development of escarpment-related areas of the quarry and regulated rehabilitation of extracted areas, but did not provide incentives or a framework for comprehensive, long term conservation of all the resource values of the property.

The quarry operator, recognizing the conservation potential of the site, initiated a proposal to donate the most significant areas to an appropriate public agency. The broad range of conservation mandates of Heritage League members and their access to a variety of funding sources allowed a rapid response to this initiative and expedited the transfer of the property to the Niagara Parks Commission.

Résumé:

Le don récent, à la commission des parcs du Niagara, d'un territoire appartenant aux carrières Queenston Ltd. illustre bien les changements récents des stratégies gouvernementales en matière de réhabilitation et de conservation.

La confiance en une législation restrictive est augmentée par des approches plus actives et moins bureaucratiques basées sur la coopération entre un réseau d'agences, également par des approches innovatrices pour l'acquisition des terres et par la promotion d'un financement et de fonctions exercés par le secteur privé. A la carrière de Queenston, une telle approche a résulté, à un moment opportun, à la protection efficace de ressources naturelles et culturelles importantes, grâce à l'implication de l'association de l'Héritage Naturel, une coalition d'agences publiques et privées engagées dans la gestion et la conservation des ressources.

La carrière, qui se trouve dans le calcaire de l'escarpement Niagara près des chutes Niagara, date du début des années 1880. Elle a été, durant une certaine période, l'une des plus grosses carrières de pierres taillées en Amérique du Nord, et est présentement une productrice majeure de pierre concasseé. On retrouve sur le site des vestiges archéologiques ainsi qu'une régénération naturelle centenaire typique. Une législation promulguée dans les années 1960-70 défendait tout développement sur l'escarpement de la carrière et contrôlait la réhabilitation des zones d'extraction; il n'y avait toutefois pas d'objectifs ou de structure afin d'assurer une conservation à long terme des ressources de la propriété.

Les opérateurs de la carrière, reconnaissant le potentiel de conservation du site, ont initié une proposition pour donner une superficie significative à une agence publique appropriée. Les mandats de conservation de l'Association de l'Héritage Naturel portant sur un large domaine ainsi que leur accès à une variété de sources de financement ont permis de répondre rapidement à cette initiative et de transférer la propriété à la Commission des parcs du Niagara.

NOTE: The CLRA Conference committee regrets that a full copy of the paper was not received in time to be included in the proceedings. For more information, we suggest you contact the author at 416-892-2656.

ESTABLISHING VEGETATION ON EROSION-PRONE LANDFILL SLOPES IN ONTARIO

ETABLISSEMENT DE LA VEGETATION SUR LES SITES D'ENFOUISSEMENT DONT LES PENTES SONT SUSCEPTIBLES A L'EROSION EN ONTARIO

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Abstract:

The erosion of a landfill cover can negatively impact upon its function and longevity. The final cover or cap over a closed landfill should perform a number of functions. Chief among these functions are:

- reduce leachate production by preventing direct rainfall infiltration;
- act as a barrier to nuisance animals such as scavenging birds and mammals;
- reduce the danger of fire breaking out in the refuse; and
- improve the aesthetics of the site by covering and containing the refuse.

Erosion of the landfill slopes can impair one or all of these cap functions resulting in increased maintenance costs and/or complaints from the public. Negative public perception of landfill closure success ultimately results in increased costs for siting future landfills.

The first year of a three year study has contributed to an understanding of the extent and severity of landfill erosion in Ontario. The first year of investigations included:

- a comparison of the degree of landfill erosion as perceived by MOE District personnel against the degree of erosion observed in the field;
- a summary of revegetation attempts and successes on the landfills visited, and
- preliminary findings on the best-available revegetation techniques.

The aim of the program is to develop an approach to remediate landfill erosion through vegetation management. A manual for the revegetation of landfills across the Province of Ontario will be one of the final products of this project.

Résumé:

L'érosion de la couverture d'un site d'enfouissement peut avoir un impact négatif sur ses fonctions et sa longévité. La dernière couverture sur un site d'enfouissement fermé doit remplir certaines fonctions. Principalement, les fonctions suivantes sont recherchées:

- réduire le filtrage au travers des détritus en prévenant une infiltration directe des eaux de pluie,
- agir comme barrière aux animaux nuisibles (les oiseaux et mammifères coprophages),
- réduire le danger d'éclatement d'un feu dans les détritus, et
- améliorer l'aspect esthétique du site en couvrant et retenant les détritus.

L'érosion des pentes d'un site d'enfouissement peut porter atteinte à l'une ou à toutes ces fonctions de couverture et entraîner une augmentation des coûts d'entretien et/ou de plaintes de la part du public. Une perception négative du public sur le succès de fermeture d'un site d'enfouissement amène nécessairement un accroissement des coûts pour situer les futurs sites d'enfouissement.

La première de trois années d'étude a contribué à la compréhension de l'ampleur et de la sévérité de ce type d'érosion en Ontario. Le compte-rendu de la première année du projet contiendra:

- une comparaison entre la perception de l'état d'érosion par le personnel des districts comparativement au degré d'érosion observé sur le terrain,
- un résumé des tentatives et succès de revégétation faits sur les sites d'enfouissement visités, et
- les conclusions préliminaires sur les meilleurs techniques de revégétation disponibles.

Un manuel pour la revégétation des sites d'enfouissement à travers la province de l'Ontario sera l'un des produits finals du projet.

INTRODUCTION

Landfills are used in Ontario for the disposal of waste materials. Sites can accept wastes from municipal, commercial and industrial sources, depending upon their licence requirements. Owned by either public or private operators, landfills vary in size from less than a hectare to over 50ha. The larger sites tend to be those that are closer to major urban areas.

Landfills take one of three general forms in Ontario: a hill or mound, a filled valley wall, or an excavated trench, backfilled with waste. The mound may have originated in depressions or excavations such as abandoned pits or quarries. Both the mound and valley filling operations can result in steep sideslopes. The backfilled trench generally results in a flat, final grade.

A soil cover is required on all waste throughout the operation. The soil cover, upon site closure, is increased with a cap material; generally between 0.5m and 2m of clay. A cover of topsoil, where available, is overlain to enhance final landscaping conditions.

The cap of soil is critical to the maintenance of an environmentally safe site. The soil placed on the landfill and, particularly, on the side slopes, both while the site is still operating and after closure, is prone to weathering forces which result in erosion.

Erosion not only results in a loss of soil but also in potential damage to the surface cap covering the refuse. That damage can lead to several problems:

- increased infiltration of rain water will accelerate the production of leachate,
- avenues for the movement of landfill gases and leachate will emerge,
- garbage will be exposed, resulting in an attraction for nuisance animals such as gulls,
- aesthetics will be reduced, and
- there will be additional costs for the repair of the damaged cap.

BACKGROUND

The Ontario Ministry of the Environment (MOE) is concerned with the problem of erosion on landfill sites but to-date the extent to which the problem occurs in Ontario has not been documented.

In 1987, the MOE commissioned a 3-year research study, the goal of which is to develop a practical approach to remediate erosion on landfill sites via proper vegetation management. A discussion of the study's main objectives and findings to-date is provided in this paper.

The 3 components of the study are:

- an overview of erosion of landfill sites in Ontario,
- identification of the best revegetation techniques,
- establishment of demonstration plots throughout Ontario.

The work undertaken in each of the study's components is briefly summarized below. This paper will emphasize the first two components.

APPROACH

Overview of Erosion on Landfill Sites in Ontario

A questionnaire was distributed to the Abatement Officers at 22 District offices of the MOE. As

their responsibility lies with the enforcement of proper landfill management, they were contacted to provide a current objective view on landfill erosion throughout Ontario.

Each participant in the survey was asked to provide:

- a description of the their landfill-related responsibilities,
- their views on landfill erosion in their specific district, and
- examples of typical landfills which had the potential to host revegetation demonstration plots.

Responses to the questionnaire provided 52 example landfills. The study team screened this number, down to 24 (4 in each of the 6 MOE regions) for field investigations.

Field data documenting physical and biological characteristics were collected during September, 1987 for each of the 24 landfill sites. The physical characterization included: collection of soil samples, and observations regarding soil type, depth, grain size, moisture, temperature and compaction. The samples were analyzed for macronutrients, pH and organic matter. The biological characterization included an assessment of the vegetative condition of each site. Percent vegetation cover, species composition and vegetation health were evaluated. The presence of site disturbances including erosion were rated using a relative scale developed during the testing of field techniques.

Identification of the Best Revegetation Techniques

The questionnaire results provided information about site history and the revegetation approach undertaken. That, in conjunction with fieldwork, provided some indication of what techniques were or were not effective.

Literature from throughout North America was reviewed. Successes and failures were evaluated. The most appropriate techniques for site preparation, planting and maintenance were investigated.

Based on the physical and biological data collected during field investigation of the 24 landfill sites, 8 sites were chosen for demonstration plots because of their suitability for the preferred vegetation management techniques identified earlier.

The plots were planted in May and early June, 1988. The characteristics of each plot varied with respect to the following parameters:

- site preparation (e.g. tillage, fertilization),
- seeding techniques (e.g. hydroseeding, seed drilling), and
- seed mixes.

There were four plots established in each of the 8 sites, generally covering an area of between 0.5 & 1ha. The number and location of plots were dictated by the availability of slopes for testing.

FINDINGS

Overview of Erosion of Landfill Sites in Ontario

The following summarizes key findings from the questionnaire sent to all MOE District offices.

- there was an 86% response rate,
- all those returned provided specific examples of landfills, on which erosion was a problem

and/or there were areas suitable for test plots,
- 73% of the respondents completed the general assessment portion of the questionnaire,
- of those, 56% reported landfill erosion to be a moderate concern and 44% reported it to be a minor concern.

A variety of problems associated with landfill erosion were reported. The exposure of buried refuse and increased remediation costs were cited most frequently. A few districts reported decreased aesthetics, nuisance wildlife problems, siltation of nearby streams and an increase in complaints from the public.

The questionnaire also revealed that the physical character of landfills vary throughout the province. For example:

- landfills are generally covered with either clay or sand, but some districts suggested that the cap was/is composed of whatever material is available (e.g. inert industrial waste),
- Southern Ontario landfills (south of Pre-Cambrian Shield) commonly use clay as the cap material,
- North of the Pre-Cambrian Shield, clay is much less available and cap materials are usually sand,
- 63% of the respondents reported that revegetation was either sometimes or never completed after landfill closure
- 37% reported that revegetation was attempted frequently or always. The majority of the revegetation efforts included only grading and seeding. Less than 20% of the districts reported any tillage or fertilization prior to planting. Thirteen percent reported tree planting was also practiced on closed landfill sites.

A summary of some field data collected is provided on Table 1. The 24 sites are separated by MOE region and district. The degree of erosion and vegetative cover entries are based on a relative scale.

Key findings are presented in a series of results-statements.

- 88% of the landfill sites inspected revealed the presence of erosion. The sites that did not, had been closed for several years, and/or did not have side slopes.
- 50% of the landfill sites inspected were open and 50% of the landfill sites inspected were closed.
- 100% of the active landfill sites displayed erosion and 83% of the closed sites displayed erosion.
- The nature of the problem of erosion differed when open and closed sites were compared. The greatest erosion occurred on active sites which were commonly characterized by steep, bare slopes, with scattered growth of volunteer or invading grasses and herbaceous plants. Plants typically occurring included Ragweed (Ambrosia artemiisifolia), Chickory (Cichorym intybus), Wild Carrot (Daucus carota) and Spotted Knapweed (Centaurea maculosa).

Erosion on closed slopes appeared prompted in some cases by: landfill gas production and resultant vegetation mortality, poor or no vegetation establishment after closure, and leachate seepage.

Identification of the Best Revegetation Techniques

Field results suggest that grading and seeding alone are not adequate to ensure the complete revegetation of landfill slopes.

A review of existing information suggests the best techniques can be grouped under three main headings:

- site preparation,
- planting, and
- maintenance.

Some initial observations are provided for each.

Site Preparation

One of the main limiting factors in revegetation success on landfills is soil compaction. Surface compaction prevents emerging seedlings from penetrating and establishing. This condition is particularly severe on sites capped with silt or clay but without a topsoil cover. Shallow tillage breaks up that surface layer allowing seedling establishment. Equipment such as the rotary tiller or spike-tooth cultivator are well suited to this work. To limit damage to the integrity of the cap, tillage should be restricted to the upper 15 cm of soil.

Topsoil or other materials high in organic matter (e.g. sewage sludge, wood waste, paper sludge), can provide a much improved growing medium. Fertilizer and lime may be required on a site-specific basis depending upon soil conditions.

Planting

Techniques for planting include hydroseeding, broadcasting and seed drilling. The effectiveness of each varies with site condition. Hydroseeding for example is particularly suited to very steep slopes where access by tractor is limited.

The material selected for planting is important. This study focused on the establishment of a dense, shallowly-rooted turf which would limit infiltration, thereby reducing the potential for damage to the landfill cap. Species selected for planting included: Smooth Bromegrass (Bromus inermis), Redtop (Agrostis gigantea), White Clover (Trifolium repens) and Timothy (Phleum pratense).

Maintenance

The vegetation systems identified in this program were aimed at providing a low maintenance landscape. Mowing in highly visible areas and periodic fertilizing were the two main needs identified.

SUMMARY

Erosion is a problem on both open and closed landfills in Ontario. Along with conditions of compaction and low fertility, surfaces of landfills often have special problems: the production of gases and leachate. Complete revegetation is part of the answer to reducing the erosion problem. The technology exists to improve on revegetation success in the province. The communication and implementation of that technology is important. Current guidelines do not provide specific advice for final landscaping. Follow-up inspections by the OMOE should be continued on beyond a 2 - 5 year horizon. A long term program should be instituted to ensure landfill cap integrity.

The end product of this 3 year investigation, a landfill revegetation manual, will be of assistance in communicating that technology.

ACKNOWLEDGEMENTS

The authors wish to acknowledge comments provided on this manuscript by Messrs. Paul Murray and Ken Dance, both of Gartner Lee Limited.

TABLE 1a: SUMMARY OF LANDFILL FIELD OBSERVATIONS

MOE Region		MOE District	Landfill Name	Size (ha)	Average Slope (degrees)	Average Slope Length (m)	Cap Material	Cover Material	Degree of Erosion	Degree of Vegetation Cover
CENTRAL		Peterborough	Bensfort	20	25	30	Clay	Clay loam	low	medium
	*	York-Durham	Beare	51	15	90	Clay	Sandy Clay	low	medium
		York-Durham	Brock West	64	10	50	Sandy Clay	-	medium	medium
	*	York-Durham	York Sanitation		14	80	Clay	Clay	low	medium
WEST CENTRAL		Cambridge	Centre Wellington	20	22	13	Clay	Sandy Clay	high	low
	*	Hamilton-Wentworth	Upper Ottawa	16	20	65	Clay	Sandy Clay	low	high
	*	Hamilton-Wentworth	Jerseyville	3	20	20	industrial material	Sandy Clay	medium	medium
	*	Welland	Pelham	12	22	36	Clay	Sandy Clay	medium	medium
SOUTH WEST		London	Southwold	30	14	21	Clay	Clay	low	high
	*	Owen Sound	Derby	4	17	13	Sandy Clay	-	medium	medium
	*	Owen Sound	Goderich		20	38	-	Sandy Loam	negligible	high
		Sarnia	Brooke		35	10	Clay	Sandy Clay	medium	low

* Indicates a closed landfill site

TABLE 1b: SUMMARY OF LANDFILL FIELD OBSERVATIONS

MOE Region		MOE District	Landfill Name	Size (ha)	Average Slope (degrees)	Average Slope Length (m)	Cap Material	Cover Material	Degree of Erosion	Degree of Vegetation Cover
SOUTH EAST		Cornwall	West Hawkesbury	6	20	30	Sandy Clay	-	medium	0
		Kingston	Kingston	10	20	45	Clay Loam	Sand	low	high
	*	Kingston	Hallowell	1	33	12	Sand	-	medium	medium
		Ottawa	Alice and Fraser	30	30	14	Sand	-	high	high
NORTH EAST		North Bay	Rexwood	3	16	35	Clay	-	medium	low
	*	Sault Ste. Marie	Michipicoten	2	40	30	Clay	Sand	low	high
		Sault Ste. Marie	Cherokee	57	30	10	Sand	-	medium	low
		Sudbury	Nickel Centre	15	30	10	Sand	-	medium	low
NORTH WEST	*	Kenora	Kenora	18	20	20	Sand	Sand and Sludge	low	high
		Kenora	Tri-municipal	2	15	20	Sand	-	low	low
	*	Thunder Bay	Auto	1	5	20	Sandy Clay	-	negligible	high
	*	Thunder Bay	East Loon	4	0	0	Sand	-	negligible	high

* Indicates a closed landfill site

THE APPLICATION OF CONSTRUCTED WETLANDS AND GEOPOLYMER TECHNOLOGIES TO RECLAIM THE ABANDONED KAM KOTIA MINE SITE, TIMMINS, ONTARIO

APPLICATION DES TECHNOLOGIES DES MARAIS ARTIFICIELS ET DES GEOPOLYMERES POUR RECUPERER LE SITE DE LA MINE ABANDONNEE DE KAM KOTIA, TIMMINS, ONTARIO

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Abstract:

Kam Kotia mine tailings are reported to have the highest tailings sulphide concentration in Canada (Kilborn, 1983). Highly acidic runoff carrying large loads of heavy metal pollutants has been occurring for over 15 years and reclamation alternatives are under review for the site.

A rehabilitation design is being developed. The site includes a partially filled open pit, old mill remnants, waste rock piles and over 400 ha of impounded and unimpounded tailings. This paper provides a review of the design process leading up to the final design. Details on the reclamation solutions for the various biophysical landscape units will be explained including the use of a geopolymer cap with a reforested cover and an extensive self-maintaining constructed wetland system. The importance of environmental performance criteria in the design solution will be discussed.

Résumé:

Les haldes de la mine de Kam Kotia sont réputées pour avoir la plus haute concentration en sulfure au Canada (Kilborn, 1983). Un ruissellement extrêmement acide transportant des quantités importantes de métaux lourds contaminants a lieu depuis plus de 15 ans et on revise présentement les options de récupération.

On développe un projet de réhabilitation. Le site comprend une mine ouverte partiellement remplie, des vestiges d'un vieux moulin, des tas de roches et plus de 400 ha de haldes. Cet article donne une revue du processus qui a condui au projet final. Des détails sur les solutions de récupération pour les différents unités de paysage biophysique seront expliqués en incluant l'utilisation d'une couverture de géopolymère avec un reboisement et la création d'un marais artificiel qui vise à isoler les sulfures de l'oxygène de l'air. L'importance de critères de performance environnementale dans le choix d'un projet sera discutée.

NOTE: The CLRA Conference committee regrets that a full copy of the paper was not received in time to be included in the proceedings. Copies of the paper will be distributed at the conference. For more information, we suggest you contact the author at 416-839-7163.

VEGETATION ESTABLISHMENT ON ASH LAGOON SURFACES USING STRAW MULCH

ETABLISSEMENT DE VEGETATION SUR DEPOTS DE CENDRESAVEC UTILISATION DE PAILLIS DE PAILLE

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Abstract:

Waste ash materials from coal-fired thermal power plants are susceptible to wind and water erosion when deposited in ash disposal sites. Stabilization of the sand-like ash surface can be accomplished by the establishment of a vegetative cover. Ash has several limitations, however, in terms of its potential as a growth medium, including potentially phytotoxic levels of boron. A study was initiated at an ash disposal site near Wabamun, Alberta, to determine the effect of organic matter applications (surface straw mulch, tilled straw mulch) on forage establishment success and boron concentrations in ash and plant tissue.

Results showed that straw mulch applications did not enhance forage establishment on bare ash. Forage yield and plant cover on the tilled mulch treatment was not significantly different than the bare ash control. The surface mulch treatment resulted in the lowest yield and plant cover. Straw mulch applications did, however, reduce the concentration of available boron within the ash surface. Organic matter tended to reduce uptake of boron by the forage crop, perhaps by tying up the boron in a non-available form. The benefits of straw mulch application may become increasingly important when stabilizing the surface of fresh ash deposits, where boron concentrations have not been reduced by leaching.

Résumé:

Les cendres volatiles et les cendres de déposition sont des résidus qui surviennent lorsque du charbon pulvérisé est brûlé par des équipements thermiques. Seulement 10 % de la production annuelle canadienne de cendres est utilisée à des fins industrielles, alors que la partie inutilisée est emmagasinée dans des sites de déposition dont les lagunes de cendres. Pour éviter les problèmes environnementaux associés à la poussière, la surface du site peut être stabilisée avec un couvert végétal.

Les cendres ont certaines caractéristiques indésirables comme médium de croissance pour les plantes. Ces dernières incluent un contenu en matière organique faible, des niveaux déficitaires de nutriments disponibles, un pH fortement alcalin et une concentration potentiellement toxique en Bore. L'objectif de cette étude était de voir, par l'application de paillis de paille sur la cendre nue, l'effet de tels traitements sur l'établissement et la croissance de la végétation et d'évaluer les changements des caractéristiques de la cendre.

Des enclos d'essais furent établis à la surface d'une de ces lagunes près de Wabamun, Alberta, et contrôlés de 1980 à 1985. Le dispositif expérimental fait au hazard contenait trois types de traitement; des parcelles de contrôle (cendre nue), des parcelles avec paillis en surface et des parcelles avec paillis et labour. Tous les enclos furent semés avec un mélange de fourrage et fertilisés annuellement. Les résultats ont montré une réduction dans la production et dans la couverture végétale avec le traitement de paillis en surface comparativement aux autres traitements. Les deux traitements avec paillis présentaient des concentrations plus faibles en Bore dans la cendre.

INTRODUCTION

The process of burning unwashed coal to generate electrical power results in the production of waste fly ash and bottom ash material. Fly ash is the airborne particulate matter removed from boiler flue gas emissions. Bottom ash is the solid residual material that accumulates at the bottom of furnaces. At Wabamun, Alberta, approximately 2 million tonnes of coal from the adjacent Whitewood Mine are burned annually, producing about 300,000 tonnes of waste ash material (TransAlta Utilities Corporation, 1988). Only a small percentage of ash is utilized for commercial purposes, so the remainder is dry-hauled to disposal sites on the mine or piped as a wet slurry to disposal lagoons. The ash deposits accumulate to form a large area of unstable and unaggregated, sand--sized particles that are highly susceptible to wind and water erosion (R.M. Hardy and Associates Limited, 1976). Surface stabilization to control erosion and dusting becomes necessary both during and after active use of a disposal site. One method of surface stabilization involves vegetation establishment.

Most ash surfaces can support growth of some plant species without soil replacement (Barber, 1973; McMinn et al., 1982). Haas and Macak (1985) found that bottom ash alone, or mixed with as much as 10% fly ash, performed as well as topsoil as a final cover in terms of its revegetation potential. Scanion and Duggan (1979) showed an average 53% survival for various woody plant species established on bare ash. Monenco Limited (1986) showed considerable success in establishing several perennial forage grass and legume species on bare ash surfaces. However, ash has a number of limitations in relation to its potential as a growth medium. Undesireable qualities of ash that can impede vegetation establishment include strongly alkaline pH, lack of organic matter, few (if any) micro and macro-organisms, deficient levels of available nitrogen and phosphorus, low cation exchange capacity and potentially phytotoxic concentrations of boron (Hodgson and Townsend, 1973; Rees and Sidrak, 1956).

Available boron occurs in soil solution at neutral to acidic pH as boric acid, and as far as is known, is the nutrient taken up by plants (Clarkson and Hanson, 1980). The major anionic forms of boron found in nature are borosilicates and borate (Buckman and Brady, 1969). Gupta et al. (1985) indicated that boron requires special attention among the essential mineral nutrients because, although the need for boron by plants is relatively small, the range between deficiency and toxicity is narrow. Hodgson and Townsend (1973) summarized phytotoxicity due to available boron levels in ash as non-toxic (0-4ug/g), slightly toxic (4-10ug/g), moderately toxic (10-20ug/g), toxic (20-30ug/g), and highly toxic (>30ug/g). The authors indicated that one method to reduce the quantity of boron available to plants was to render the boron insoluble in situ.

Gupta et al. (1985) indicated that when boron becomes available in the soil, part of the boron remains in soil solution and part is fixed or retained by soil particulates. Boron retention was dependent on the boron concentration in solution, soil pH, texture, CEC, exchangeable ion composition, type of clay, mineral coatings on the clay and organic matter. The authors indicated that the association with organic matter may originate from boron assimilation in microbial biomass

rather than chemical adsorption. Evans (1987) also related boron retention to soil pH and, for conditions of alkaline pH, found that boron retention increased as the content of soil organic matter increased. The author suggested that borate was an important species in boron retention, either through retention as inner sphere complexes associated with mineral surfaces by ligand exchange processes or by complexation with soil organic matter.

Ash disposal sites in central Alberta frequently contain potentially phytotoxic concentrations of boron, which limits vegetation establishment success during surface stabilization and reclamation. McCoy et al. (1981) identified boron as a dominant anion in some Alberta fly ashes.

A series of experimental plots were set up to identify suitable methods of straw mulch application to ash that would enhance vegetation establishment success. This paper reviews the effect of straw mulch applications on forage yield, plant cover, plant tissue boron and ash boron levels. Straw mulch was selected as an ash amendment due to its local availability, low cost and suitability for erosion control. As an ash amendment, straw mulch had the potential to reduce concentrations of boron, as well as improve soil fertility, cation exchange capacity, aeration, water holding capacity and microbial activity.

METHODS AND MATERIALS

The study area was in central Alberta, approximately 65 km west of Edmonton (Sec 10 - Twp 53 - Rge 4 - W5). The area has a sub-humid to humid climate, averaging 504mm of precipitation annually (Environment Canada, 1982). The growing season consists of an average 104 frost-free days (May 29 - September 11) and has about 1350 degree days above 5^0C. Annual precipitation totalled 459mm in 1979, 625mm in 1980, 461mm in 1981, 620mm in 1982, 406mm in 1983, 536mm in 1984 and 482mm in 1985 (Monenco Limited, 1987). The mean daily temperature was 2.7^0C in 1979, 3.4^0C in 1980, 5.5^0C in 1981, 1.3^0C in 1982, 3.1^0C in 1983, 3.7^0C in 1984 and 3.3^0C in 1985.

A series of plots were established on an exposed ash lagoon surface (Old West Lagoon) adjacent to the Wabamun thermal power plant in 1979. The completely randomized experimental design had three ash treatments and was replicated three times. Treatments included a surface straw mulch application, a tilled straw mulch application and an untreated control (no straw mulch).

Plots measured 2m wide x 7m long and were randomly located within the experimental area of the ash lagoon. The chemical and physical characteristics of the ash material has been shown in Table 1. After all plots had been

TABLE 1: PROPERTIES OF ASH MATERIAL PRIOR TO PLOT CONSTRUCTION IN 1979.

Ash Property	Sample Depth 0-15 (cm)	15-30 (cm)	30-45 (cm)
pH	8.5	8.6	10.0
EC (ms/cm)	0.19	0.19	0.26
SAR	0.1	0.1	0.2
$CaCO_3$ equiv.(%)	6.2	16.3	5.8
Avail. B (ug/g)	8.5	9.3	19.5
Sand (%)	74	93	74
Silt (%)	23	6	24
Clay (%)	3	1	2
Texture	Sandy Loam	Sand	Sandy Loam

rototilled, straw mulch was applied to selected plots at a rate of 17t/ha. This application rate was approximately 5 to 10 times the normal application rate for agricultural soils. Surface straw mulch treatments were covered with fish-netting to hold straw in place. Tilled straw mulch treatments were rototilled after mulch application to a depth of about 15cm.

A forage mixture containing slender wheatgrass (Agropyron trachycaulum), creeping red fescue (Festuca rubra spp. rubra), smooth bromegrass (Bromus inermis), timothy (Phleum pratense), red clover (Trifolium pratense), alsike clover (Trifolium hybridum) and alfalfa (Medicago sativa) was seeded at rates of 13, 12, 12, 7, 2, 2 and 2kg/ha, respectively. The forage mixture was seeded in the spring using a hand-operated broadcast spreader. Seed was raked and packed into the ash prior to mulch application on the surface mulch treatment and after mulch application and rototilling on the tilled mulch and control treatments. Fertilizer was applied annually at rates of 50 to 100kg N/ha, 36 to 100kg P/ha, 0 to 100kg K/ha and 25 to 285kg S/ha to maintain plot vegetation.

Forage yield was determined by clipping the standing biomass from a 1m x 5m area within each plot at 5cm above ground level. Annual forage samples were clipped in late August to early September. Sampled forage material was oven-dried at 3^{0}C for 48 hours and weighed. A composite sample of grass leaf tissue was collected prior to the harvest and sent to the laboratory for analysis of hot water extractable boron content (McKeague, 1978). Estimates of plant cover were made along three 1 m transects within each plot (point intercept method) prior to the plot harvest. A composite ash sample was collected after the crop harvest from two depths (0-15, 15-30cm) within each plot and analysed for available boron.

Yield, plant cover, plant tissue boron and ash boron data were analyzed statistically using a completely randomized analysis of variance procedure for the years 1980 to 1985 (Steel and Torrie, 1980). Differences among treatments and years for individual parameters were identified using the least significant difference (LSD) test at a 10% level of significance.

RESULTS AND DISCUSSION

Forage Yields

Mean forage yields over six years were lower on the surface mulch treatment than the tilled mulch treatment and bare ash control (Table 2). The surface mulch treatment had the lowest forage yield in almost every year. In 1985, patches of straw mulch still littered portions of the surface mulch plots. There was no difference between forage yields measured on the tilled mulch treatment and the bare ash control, although there was a trend toward higher yields on the tilled mulch treatment in most years.

Additions of organic matter have the potential to increase crop yields by improving soil fertility, cation exchange capacity, soil aeration, water holding capacity and microbial activity (Hausenbuiller, 1982). Forage yields did not significantly improve on the ash lagoon surface with straw mulch application, likely due to the slow decay of organic matter. The lack of sufficient micro and macro-organisms essential for organic matter decomposition and nutrient cycling may be partly responsible for

TABLE 2: DRY WEIGHT (g/m^2) OF FORAGE CROP ON ASH AS AFFECTED BY STRAW MULCH TREATMENTS

Mulch Treatment	Year						Mean
	1980	1981	1982	1983	1984	1985	(6Yr)
Surface	110 b*	231 b	352 b	321 b	344 b	510 b	311 b
Tilled	198 a	477 a	504 a	546 a	677 a	616 a	498 a
None	190 a	404 a	497 a	505 a	619 a	703 a	486 a
S.E.	25	33	44	53	64	85	32

* Means down the same column followed by the same letter are not significantly different at the 10% level (LSD).

TABLE 3: PLANT COVER (%) OF SEEDED FORAGE SPECIES ON ASH AS AFFECTED BY STRAW MULCH TREATMENTS

Mulch Treatment	Year						Mean
	1980	1981	1982	1983	1984	1985	(6Yr)
Surface	18 c*	56 a	80 b	86 b	78 b	89 b	68 b
Tilled	57 b	87 a	99 a	100 a	100 a	98 a	90 a
None	76 a	87 a	100 a	100 a	98 a	99 a	93 a
S.E.	2	17	5	4	8	2	4

* Means down the same column followed by the same letter are not significantly different at the 10% level (LSD).

the slow decay process, which was especially apparent on the surface mulch treatments. In addition, the lack of available nitrogen within ash material likely was a major limiting factor in the decay process.

Plant Cover

Mean plant cover of seeded forage species over six years was lowest on the surface mulch treatment compared to the tilled mulch treatment and the bare ash control (Table 3). In 1980, plant coverwas higher on the bare ash control compared to both mulch treatments. By 1982, the tilled mulch treatment and bare ash control had achieved full plant cover, while the surface mulch treatment had significantly less. This pattern of reduced plant cover on the surface mulch treatment remained the same for the duration of the experiment.

Forage crop establishment was not enhanced by the straw mulch application on either mulch treatment. Both mulch treatments had less plant cover in 1980 than the bare ash control. Plant cover on the tilled mulch treatment recovered quicker than the surface mulch treatment. The heavy surface mulch application appeared to inhibit forage establishment by creating a cool, shaded environment that was unsuitable for seed germination and forage seedling growth.

Lighter surface mulch applications (1120kg/ha) have proven beneficial to forage establishment when reclaiming minespoil (McGinnies, 1987).

Plant Tissue Boron Concentration

Mean plant tissue boron concentration over the last two years of the experiment (1984 and 1985) was not significantly different between treatments (Table 4). However, there was a trend toward higher plant tissue boron levels on the bare ash control compared to the tilled mulch and surface mulch treatments.

TABLE 4: PLANT TISSUE BORON (ug/g) CONCENTRATION OF FORAGE ON ASH AS AFFECTED BY STRAW MULCH TREATMENT

Mulch Treatment	Year 1984	Year 1985	Mean (2 Yr)
Surface	168 a*	79 a	123 a
Tilled	169 a	53 a	110 a
None	193 a	87 a	140 a
S.E.	21	15	13

* Means down the same column followed by the same letter are not significantly different at the 10% level (LSD).

The data indicated a tendency for additions of organic matter in ash material to reduce uptake of available boron in plant tissue. However, variability in plant tissue boron levels made this difficult to confirm statistically. Gupta (1979) found that it was common for different parts of a single plant to exhibit a wide range in boron content, which may increase or decrease with age of the plant part sampled.

In general, levels of boron in plant tissue can be characterized as deficient from 0 to 20ug/g, adequate from 25 to 100ug/g and potentially toxic over 200ug/g (Branford 1966). The author indicated that excess boron commonly produces a progressive necrosis of the leaf, beginning at leaf tips and margins as achlorotic yellowing and progressing to a burned or scorched appearance. Mean plant tissue boron levels over the two years were more than adequate (110 to 140ug/g) and approached toxic levels within the forage crop in 1984. However, symptoms of boron toxicity were not generally evident during the experiment on any treatment, likely due to boron leaching from the ash surface prior to plot establishment.

Ash Boron Concentration

Mean ash boron concentration (hotwater extractible) measured over four years at a 0-15cm depth was higher on the bare ash control than the tilled and surface mulch treatments (Table 5). There was a similar trend toward higher mean ash boron levels at the 15-30cm depth on the bare ash control compared to both mulch treatments. Higher levels of ash boron at the 0-15 and 15-30cm depths were measured on the tilled mulch treatment compared to the surface mulch treatment in most years.

The data suggests that available boron was tied up in a non-available form within the ash treatments containing applications of organic matter. The lower level of boron in the lower yielding surface mulch treatment compared to the tilled mulch treatment may have been due to lower water use and, therefore, more leaching.

In general, levels of boron in agricultural soil can be characterized as deficient from 0 to 1ug/g, adequate from 1 to 20ug/g and toxic over 20ug/g (Branford 1966). Mean boron levels over six years within the first 30cm of ash

TABLE 5: ASH BORON (ug/g) CONCENTRATION UNDER A FORAGE CROP AS AFFECTED BY STRAW MULCH TREATMENT

Mulch Treatment	Year 1980	1982	1984	1985	Mean (4 Yr)
	0-15 cm Depth				
Surface	4.2 c*	2.3 b	6.2 a	4.5 a	4.3 b
Tilled	5.5 b	3.0 ab	5.9 a	4.6 a	4.7 b
None	7.4 a	3.5 a	8.3 a	7.8 a	6.8 a
S.E.	0.34	0.37	1.72	1.33	0.82
	15-30 cm Depth				
Surface	4.7 c	2.0 a	9.5 a	5.8 c	5.5 a
Tilled	6.2 b	3.1 a	7.1 a	6.9 b	5.8 a
None	8.8 a	3.7 a	12.8 a	10.2 a	8.9 a
S.E.	0.65	0.59	3.98	1.58	1.55

* Means down the same column followed by the same letter are not significantly different at the 10% level (LSD).

ranged from 4.3ug/g to 8.9ug/g across all three treatments and were not considered toxic. These levels were low compared to boron levels deeper within the ash profile. Townsend and Gillham (1975) identified the beneficial effects of leaching on ash to be used as a plant growth medium, such that allowing the ash surface to leach for three years resulted in considerably lower boron concentrations. The authors indicated that boron levels decreased with time and leaching, but that the process may be slow due to the progressive hydrolysis of borosilicates in the glassy phase of ash.

CONCLUSIONS

Straw mulch applications did not significantly enhance forage establishment on bare ash. Forage yield and plant cover on the tilled mulch treatment was not significantly higher than that measured on the bare ash control and was lowest on the surface mulch treatment. Poor vegetation establishment success on the surface mulch treatment was attributed to the cool, dark environment created by the heavy mulch application which inhibited seed germination and growth. The benefits of both straw mulch applications appeared to be reduced by the slow decay of organic matter, likely due to a deficiency of micro-organisms and available nitrogen.

Straw mulch applications, however, tended to reduce the uptake of boron by forage plant species, perhaps by tying up the boron in a non-available form. Applications of organic matter may become increasingly important for vegetation establishment when attempting to reduce boron levels in fresh ash deposits, or when attempting to establish less boron tolerant plant species on leached ash surfaces.

ACKNOWLEDGMENTS

This study was funded by and conducted using the facilities of TransAlta Utilities Corporation. The author wishes to thank Ms. Holly Quan of that company for her assistance with this program over the years.

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THE COSTS OF RESTORING TO AGRICULTURE

LES COUTS DE LA REHABILITATION AGRICOLE SELON UNE PERSPECTIVE D'EXPLOITANT D'AGREGATS

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Abstract:

Much of Ontario's primary aggregate resource is under prime agricultural land. Returning aggregate extraction lands to agriculture is a practical example of a sequential land use which attempts to optimize use of the land resource. Good preplanning and the proper operating practices are equally important for success in agricultural rehabilitation. With help from neighbouring farmers, the agriculture ministry, our own research and trial and error we have developed rehabilitation methods that we use in various combinations when returning lands to agriculture. Our three major considerations are: proper handling of soil materials, establishing grades and crop management after restoration. Case studies of rehabilitation practices at two locations will outline our approach and relate some of the lessons we have learned.

Résumé:

Une grande partie des sources d'agrégats en Ontario se trouvent sur des terres agricoles de premier ordre. Le retour à la vocation agricole des terrains exploités pour les agrégats représente un exemple pratique du principe d'utilisation séquentielle des terres. La réhabilitation à des fins agricoles dépend tout particulièrement d'une bonne planification antérieure et de pratiques opérationnelles adéquates. Avec l'aide d'agriculteurs voisins et du ministère ontarien de l'agriculture et grâce à plusieurs projets de recherches qui ont connu divers succès et échecs, nous avons développé des techniques agraires particulièrement efficaces en matière de réhabilitation agricole. Nos trois considérations majeures sont: la manipulation adéquate des divers couches de sols, l'établissement de pentes acceptables et la gestion des espèces après le programme de restauration complété. Notre méthode sera illustrée par deux projets spécifiques qui montrera les leçons apprises au cours des années.

INTRODUCTION

Aggregate extraction is a major industry in Ontario with an annual production of 120 million tonnes (1986) of sand, gravel and stone. Approximately 40% of this is quarried from sedimentary bedrock with the remainder being extracted from glacial deposits laid down during the last ice age. This discussion will address the rehabilitation of sand and gravel pits in these glacial deposits.

The operation of pits and quarries in Ontario is regulated by the Pits and Quarries Control Act (Province of Ontario 1972), administered by the Ministry of Natural Resources. As part of the licensing process, site plans must be filed which specify existing conditions, operational plans and a rehabilitation plan for the property. Far from merely re-establishing ground cover, many operators are committed to returning the extracted land to agricultural production.

If the surrounding land use indicates that agriculture would be the most desirable afteruse a number of steps must be taken to reach this goal. What type of agriculture predominates in the area and is it possible to suc-

cessfully return the land to productivity? Will agriculture be the eventual end use or will it be another interim use as in the case of land annexed by an expanding city? Will the economic returns justify the costs of restoring to agriculture? Some of these questions would require a crystal ball to answer but a direction must be chosen so that a realistic plan can be charted.

Thorough planning before the first machine is on the ground is essential to the success of any rehabilitation plan. Time and effort spent organizing the operation at this stage will return benefits when extraction is under way by minimizing handling of soil materials, logical planning of stripping sequence and efficient use of machinery.The key, then, is having an organized plan and following through with careful and correct operational practices.

Once a workable plan has been established (and assuming the licence has been granted) rehabilitation begins, since proper handling of soil materials at this stage is necessary to preserve their value for later use. Topsoil and subsoil must be stripped and stored separately so that they may be reapplied separately. If topsoil is stripped when wet serious structural damage can occur which is difficult to remedy and adds cost to the later stages of restoration.

The choice of equipment used in stripping and hauling can also have a great effect on soil material quality. Stripping can be done with a bulldozer pushing topsoil and subsoil into separate windrows which can then be loaded into off-road dump trucks by a front-end loader for hauling to the rehabilitation site. Rubber-tired scrapers are often used to accomplish the stripping, hauling and placing of soil materials with one machine but this method becomes expensive when hauling distances exceed several hundred metres. As well, heavy scrapers compact the soil much more than using a track-type bulldozer to spread materials on the rehabilitation site. Front-end loaders and off-road trucks are commonly used in aggregate operations which is a further advantage to their use since slack time in operations can free up these machines for rehabilitation use.

Both of these methods require careful operators so that topsoil and subsoil are separated as much as possible. It makes sense either way to move the soil materials as short a distance as possible and as little as possible. If a rehabilitation site is not ready then either the soil should be left in windrows to be moved later or stored as close the eventual site as possible without interfering with operations.

A grading plan for the site should be established, keeping in mind the crop to be grown. Obviously, an area to be used for livestock pasture will not require as detailed a grading plan as one which will grow tender fruit crops. The contours of an orchard grading plan will provide air drainage to prevent frost pockets as well as surface water drainage. If the area is to worked with machines or will be cultivated annually slopes should be shallow to minimize erosion and be safe to operate machinery on.

Rough grading of the pit floor can now take place. In many cases the excavation has bottomed out on undesirable material such as glacial till or clay and silt which can be graded to conform to the grading plan. Often, however, excavation has gone below the proposed rough grade and backfill-

ing with clean unmarketable pit material will be necessary.

Before spreading soil materials the pit floor should undergo deep tillage with a subsoiler attached to a large bulldozer. This will loosen compaction due to heavy wheeled equipment traffic in the course of excavation. Once this is complete the subsoil can be spread, preferably to a depth of 50 - 60cm. At this stage the ground should be deep tilled again to aid internal drainage before the topsoil is applied. The depth of topsoil necessary will vary firstly with the amount available but also with the needs of the intended cropping system. A perennial grass cover may only require 8 or 10cm while a rotational field crop system or specialty crop may not thrive without 20 to 30cm. One more deep tilling and the construction equipment gives way to agricultural equipment.

The next process, depending on the stoniness of the topsoil, will be either cultivation or stone-picking. If the topsoil is reasonably stoney, rock windrowing and picking with agricultural machines should take place, followed by cultivation with disc harrows. If the topsoil is only slightly stoney these processes can be reversed since disc harrowing will bring the rocks to the surface so they may be picked easier. It is unlikely that the topsoil will be completely stone-free.

At this point, amendments of any type which will increase the organic matter and moisture holding capacity of the soil should be applied and incorporated by cultivation. Livestock manure, if available, is very valuable for the organic matter and nutrients it provides. Some experimentation is currently being done with blended primary and secondary paper waste resulting from the newspaper recycling process. This material is being composted for a number of months and then incorporated with the topsoil by spreading over top and cultivating. If it is late in the growing season, fall rye could be broadcast on the area to be disked in as green manure in the spring.

Soil samples should be taken to determine the level of fertility required for the crop to be grown. Although the site may now be ready in terms of grading, stonepicking and fertility and could be seeded, experience has shown that an intermediate crop stage is necessary before a return to full-scale production. Whether the land in intended for sour cherries or grain corn the soil condition will benefit from the planting of a legume or legume/grass mixture for the first few years of rehabilitation. Legumes such as alfalfa or trefoil are desirable because they send down aggressive root systems which help loosen the topsoil further, they fix atmospheric nitrogen and convert it to a plant-usable form and they add organic matter to the restored soil. After two to three years of this regime, the legume crop can be plowed under as a further enhancement to the soil resulting in a more properly conditioned seedbed and a greater chance of success in subsequent cropping systems.

CASE STUDY: TCG MATERIALS LIMITED

TCG Materials Limited currently operates sand and gravel pits in four main locations in Southern Ontario with an annual production of approximately 3 million tonnes. The Company's holdings of aggregate land total nearly 1200ha, 244ha of which are under active extraction. A further 400ha. are presently leased or rented to farmers and will eventually be

extracted. Most of the land currently being extracted was previously farmed and out of 20 licences held under the Pits and Quarries Control Act, 12 call for rehabilitation to agriculture after extraction. In fact, we anticipate several different after-uses at our various operations. In 1983 a nine hole addition to a London area golf course was opened on a 26ha. depleted property. In Puslinch Township near Guelph we have a below-water dig creating a lake with well graded side slopes which are being revegetated and reforested as we progress through the deposit. This site will either be a conservation/wildlife area or estate lots.

Our agricultural rehabilitation experience centers on two major operations in Fonthill and Brantford. In Fonthill we are rehabilitating towards tender fruit production as a final use. In fact, extraction in the final phase of an adjacent licence recently obtained is conditional on the success of our tender fruit rehabilitation on the original licensed area. This type of condition on a licence may well become more prevalent in the future but, as far as we know, it is the only one of its kind in the province.

In Brantford we are rehabilitating to field crop agriculture with satisfactory crops of hay, corn and wheat being grown. The land use horizon for this particular pit has changed, though, since the City of Brantford has expanded its borders and now includes much of our current Brantford operations. This land will likely be developed for industrial use within the next ten years so agriculture is now an interim land use, as aggregate extraction was before it.

Since 1971 TCG has rehabilitated 141 hectares to the requirements of the Pits and Quarries Control Act. In addition, we have reached a steady state in our present land utilization, each year closing or rehabilitating as many hectares as we open up for new extraction.

On the following pages are tables showing some of the machinery we use in agricultural rehabilitation and some representative costs of the work they do. Table 1 lists machinery, its use and the hourly rate.

Table 2 is a breakdown of rehabilitation costs at our Fonthill pit where soil materials are being hauled down from the top of the active face to a site on the pit floor. It should be noted that more soil material per hectare is needed in Fonthill because of the needs of the tender fruit crop.

Once the initial seeding of a legume/grass mixture is established, hay crops are harvested for 3 to 4 years to condition the soil for planting fruit trees. During this time, yearly soil samples are taken and fertility applied according to laboratory analysis. Backhoe test pits are also dug periodically to determine the extent of legume root development as an indication of soil bulk density. Fruit trees are purchased from commercial nurseries with varieties chosen in consultation with extension workers from the Ontario Ministry of Agriculture and Food at the Vineland Horticultural Research Station and neighbouring fruit growers.

The trees are planted with the help of cooperative area fruit growers who are also contracted to carry out the foliar pesticide spray programs and assist in harvesting and marketing the fruit crops. Routine orchard management tasks such as weed control, pruning, cover crop planting and

mulching are carried out by TCG personnel.

Table 3 relates the costs of rehabilitating to field crops at our Brantford operation, initially to hay in this case. The costs of subsoiling and topsoiling this area are much less than in Fonthill for two reasons. Firstly, the rehabilitation site is immediately adjacent to the working face and is much shallower than in Fonthill. This allowed the soil layers to be pushed aside while extraction took place then bulldozed a relatively short distance back onto the side. Secondly, there was much less topsoil and subsoil on site, calling for more careful spreading but much less actual machine time. Correspondingly, a lower valued crop is being grown here.

The costs which have been related on previous pages indicate some of the expense of the actual rehabilitation process, moving the soil and convincing it to yield crops again. What aren't shown here are the costs of designing the site plans which are the blueprint for rehabilitation and the expertise and forethought they represent. The Fonthill pit floor, for example, has been carefully designed in consultation with agrometeor- ologists and climatologists to result in proper air flow through our orchards and those of neighbouring growers. The advice and cooperation of these same neighbouring growers on pruning and other orchard management tasks is invaluable to our efforts.

In addition, we have not placed a value on the knowledge and experience of the machine operators involved. Without careful attention to all of the details of agricultural rehabilitation the chances of success are dubious.

If successful rehabilitation to agriculture is gauged by productivity, we feel we have attained a moderate level. Our crops are now yielding only slightly less than on neighbouring undisturbed land. This indicates to us that this type of rehabilitation is technically possible. In areas where the surrounding land use is still predominantly agriculture, restoration to farmland is the only responsible thing to do. However, as the social and economic climate changes we wonder, for instance, what the future will bring to our sour cherry orchardin Fonthill. Will freer trade with the United States wipe out Niagara Peninsula fruit growers or will there be an attempt to preserve some self-sufficiency in tender fruit crops.

Other than the fact that it is reclaimed land, we are managing our orchards and crop land using commonly accepted practices with only slight modifications. Perhaps we should be a little more "un"-conventional and experiment with different crops and production systems. Why not nut trees in Fonthill or fish protein in ponds in Aberfoyle? Recognizing that agriculture itself is in a constant state of change, we must keep up with those changes to maintain our committment to agriculture rehabilitation. As a company we are proud of what we have accomplished so far and we look forward to tomorrow's challenges.

TABLE 1: MACHINERY USED IN AGRICULTURAL REHABILITATION

Description	Use	Hourly Rate (incl. operator)
Caterpillar D8L 325hp. Bulldozer with ripper	Stripping topsoil, subsoil Stockpiling soil materials Grading and levelling soil materials Deep tillage	$ 152.41
Caterpillar 988B Front end loader 5.5 cu.metre bucket	Loading, hauling topsoil and subsoil	$ 151.95
Euclid or Terex Off-road dump truck 32 tonne capacity	Hauling topsoil, subsoil	$ 111.77
Massey Ferguson 245 45 hp Farm tractor	Agricultural subsoiler, Disc harrowing Cultivating Broadcast seeding & fertilizing Stone windrowing/picking Drag harrowing, packing Spreading manure	$ 35.00
Disc harrows, cultivator	Tillage operations, incorporation of soil amendments	$ 5.00
Rock windrower, rock picker	Stone picking	$ 10.00
Broadcast spreader	Seeding, fertilizing	$ 5.00
Drag harrows, Packer seed covering	Final seedbed preparation,	included with tractor
Manure spreader	Spreading paper waste, manure	$ 5.00
Case 580C Loader/ backhoe	Loading paper waste, manure in manure spreader	$ 55.00

TABLE 2: SAMPLE COSTS OF REHABILITATING FARMLAND - FONTHILL

Approximately 8 hectares pit floor being rehabilitated to tender fruit. 1987 - 1988

Job description	Machine/material	Hours	Total Cost
Loading topsoil & subsoil	Caterpillar 988B Loader	98.75	$ 15,005
Hauling topsoil & subsoil	Euclid/Terex Off-road dump trucks	166.75	$ 18,637
Grading, levelling, ripping pit floor and soil materials at rehab. site	Caterpillar D8L Dozer	136.00	$ 20,728
Surveying, setting grade stakes	Survey crew, company personnel		$ 1,361
Spreading paper waste on rehab. site (waste is free)	Case loader/backhoe Farm tractor & manure spreader	20.00 20.00	$ 1,100 $ 800
Disc harrowing rehab. site	Farm tractor & disc harrows	7.00	$ 280
Rock windrowing/picking	Farm tractor, rock windrower, rock picker	20.00	$ 900
Drag harrowing	Farm tractor, drag harrows	4.00	$ 140
Spreading fertilizer 6-24-24 @ 330 kg./ha. Fert. cost:$ 274/1000kg.	Farm tractor, broadcast spreader	4.00 2640kg	$ 140 $ 723
Seeding alfalfa/timothy mixture @ 22 kg. per ha. Seed cost: $ 7.37/kg.	Farm tractor, broadcast spreader	3.00 176kg	$ 120 $ 1,300
Drag harrowing, packing	Farm tractor, drag harrows, pacer	4.00	$ 140
TOTAL COST BEFORE PLANTING FRUIT TREES:			$ 61,374
Cost per hectare rehabilitated:			$ 7,672
Estimate of additional cost to plant fruit trees (2000 @ $6.00/tree) in 4 years:			$ 12,000
Cost of trees per hectare:			$ 1,500

TABLE 3: SAMPLE COSTS OF REHABILITATING FARMLAND - BRANTFORD

Approximately 4 hectares pit floor being rehabilitated to field crops
1987 - 1988

Job description	Machine/material	Hours	Total Cost
Levelling, ripping pit floor, spreading subsoil	Caterpillar D8L Dozer with ripper	43.00	$ 6,554
Spreading and grading subsoil and topsoil	Caterpillar D8L Dozer	25.00	$ 3,810
Disc harrowing rehabilitation site	Farm tractor, disc harrows	5.00	$ 200
Raking roots from rehabilitation site	Farm tractor, cultivator	3.00	$ 150
Drag harrowing rehab. site before and after seeding	Farm tractor, drag harrows	4.00	$ 140
Seeding and fertilizing rehabilitation site (late Fall seeding date)	Farm tractor, broadcast spreader	6.00	$ 240
	Seed: Fall Rye @ 20kg./ha.	80kg	$ 20
	Fertilizer: 6-24-24 @ 100kg./ha.	400kg	$ 98
Disc harrowing fall Rye (following spring)	Farm tractor, disc harrows	5.00	$ 200
Rock windrowing/picking	Farm tractor, rock windrower, rock picker	10.00	$ 450
Drag harrowing before and after seeding	Farm tractor, drag harrows	4.00	$ 140
Fertilizing rehab. site	Farm tractor, broadcast spreader	3.00	$ 120
	Fertilizer: 6-24-24 @ 335kg./ha.	1340kg	$ 367
Seeding rehab. site with coated alfalfa/timothy/ perennial ryegrass mixture	Farm tractor, broadcast spreader	2.00	$ 80
	Seed:Mixture @ 17kg./ha.	68kg	$ 476
TOTAL COST TO ESTABLISH HAY CROP:			$ 13,045
Cost per hectare to rehabilitate:			$ 3,261

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FIELD MANUAL FOR RECLAMATION OF SALT CONTAMINATED SOILS

MANUEL POUR LA RECUPERATION DES SOLS CONTAMINES PAR LES EAUX SAUMATRES

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Abstract:

A field Manual for treating saltwater-contaminated soil was prepared by the Production Research Department of Esso Resources Canada Limited and Husky Oil Operations Limited. The purpose of the manual was to provide field and plant operations with a practical guide for reclaming brine spills on mineral (agricultural) soil. The manual covers background scientific theory about how saltwater affects the soil, initial steps for treating new spills, how to assess a spill site and how to design, implement and monitor a reclamation program.

Résumé:

Un manuel pour le traitement des sols contaminés par les eaux saumctres a été préparé conjointement par les Ressources Esso du Canada (Département de la recherche en production) et par Husky Oil (Husky Oil Operations Ltd.). Le but de ce manuel était de fournir aux opérateurs d'entreprise et aux travailleurs sur le terrain un guide pratique pour récupérer les déversements d'eau saumctre sur un sol minéral (agricole). Le manuel parcoure la théorie scientifique sur les effets de l'eau salée sur le sol. Il traite également des démarches initiales afin de traiter de nouveaux déversements, de l'évaluation d'un site de déversement et de quelle façon concevoir, exécuter et contrôler un programme de récupération.

INTRODUCTION

Saltwater is often produced with crude oil and must be separated from it at a processing facility prior to disposal by deep-well injection. As oil producing fields have declined in productivity, larger volumes of saltwater are being produced. This trend has led to higher pipeline pressures and corrosion rates which have resulted in an increasing frequency of saltwater spills. In response to this situation, the oil industry has developed research programs that investigate brine spill reclamation for a variety of soil and climatic conditions.

Most reclamation programs are implemented by area field operators. These individuals often have a variety of production related responsibilities and are rarely reclamation specialists. The knowledge and experience they gain on the job is inconsistantly transferred to new personnel. A reclamation field manual was prepared to provide a training tool for field staff responsible for reclamation and to provide a method for transferring new technology gained from recently completed research.

BACKGROUND SCIENTIFIC THEORY

Background scientific theory was included in the manual to provide a description of the chemical processes involved. With some knowledge of the theory, the field operators have demonstrated that they can more effectively interpret soil sample analyses, assess spill sites and develop appropriate reclamation programs.

The background information that is included in the manual focuses primarily on the ion exchange that takes place between sodium and calcium/magnesium during a spill. The surfaces of the soil clay particles act as an ion exchange medium and competition between calcium/magnesium and sodium for the active sites on the particles is concentration dependent (Richards et al 1969).

The theory section is concluded by describing the effects of a saltwater spill on the soil. Soil dispersion is defined as a disaggregation of clay particles that results in hardpanning of the surface and a reduction in water movement down through the soil profile. High soil electrical conductivity is mentioned because it limits the ability for plants to uptake water and nutrients (Henry et al). Reduced soil microbial activity is indicated which limits soil aeration and fertility (Freeman and Innes, 1986).

TREATMENT OF NEW SPILLS

Treatment of new spill sites was discussed separately from treatment of established spill sites because research has indicated that sodium does not displace calcium/magnesium from the clay surfaces until the soil has either dried out or has been flushed with fresh water such as during a rain storm (Buchman and Brady, 1970). As a result special steps were outlined in the manual for reclaiming new spill sites which are to be specifically implemented prior to a drying or flushing cycle. These procedures have been found to greatly reduce the environmental impact of a new spill and greatly reduce the long term cost of reclaiming a new spill site.

The important features which are stressed in this section include:

1. fast response
2. limit the effected area as much as possible
3. seasonal variations in spill response
4. choice of chemical treatment.

A fast response is emphasized so that treatment begins before a drying or flushing cycle occurs. The extra costs for items like employee overtime pay or premium equipment rentals are small when compared with the extremely expensive programs required to recover features such as stocked fishing ponds, agricultural land, shelterbelts and sloughs or dugouts, especially those that serve as a water sources for cattle.

Limiting the size of the effected area is desirable for obvious reasons. The methods recommended for achieving size control are discussed and include techniques such as vacuuming up excess liquid to remove spill material quickly and creating drainage trenches and collection wells for controlling the direction of spill flow. It should be stressed that an important step in limiting the size of a spill area is to properly assess the site before clean up begins. It is not enough to know how to minimize the spill area; it is also important to prioritize where to concentrate efforts first.

Different responses are required for different seasons. In particular, the chemical amendment applications required for winter are different than for the other seasons. For example, calcium nitrate ($Ca(NO_3)_2$) is a recommended amendment for new spills in the warmer months because of its

greater solubility; however, when the ground is frozen, gypsum is equally effective and it is cheaper.

Calcium nitrate is a chemical amendment which should be used only in a new spill situation prior to dispersion taking place. The high solubility of this amendment enables it to supply calcium ions more effectively throughout the spill-affected zone than gypsum. Fertilizers and organic amendments such as manure are needed to quickly promote vegetation growth and to maintain the soil permeability. The types and quantities of these amendments are discussed in the manual.

SITE ASSESSMENT

The site assessment is important because it forms the basis of the reclamation program design. To properly conduct a site assessment, the following steps were highlighted in the manual:

1. Preparation of a site diagram of map.
2. Description of the spilled material.
3. Description of site parameters such as topography, vegetation, water table depth, soil texture, permeability and structure.
4. Determine the relevant climatic conditions.

The manual discusses the above issues and provides a spill site assessment form which can be used to summarize the information. A copy of the form is given in Figure 1. The first section of the form, entitled Spill Assessment, deals mostly with quantifying and qualifying the spilled material. The second section is called Site Assessment and addresses the site parameters. The third and last section is the Site Drawing. A small grid is provided for a diagram and a list is given of the important items that should be included on it.

The quantity and quality of the material spilled is of great importance. A spill consisting of $5m^3$ will require a smaller reclamation program than one of $50m^3$. Similarily a spill that is 80% oil and 20% saltwater will need a different treatment than one consisting of 20% oil and 80% saltwater.

Site parameters such as soil texture, structure and permeability indicate the soil susceptability to dispersion and the related issue of hardpanning. Topography and water table depth indicate the natural drainage of lack of it. This knowledge will assist the operator in determining his drainage and sub-soiling needs.

The site diagram is highly recommended because it is the most effective way of depicting the details of the spill area. If it is drawn carefully, the cost and physical extent of a reclamation program can be more quickly determined. It can also serve as a concise record to measure reclamation progress against.

Finally, climatic conditions are discussed because they will often dictate the need for irrigation systems (White and de Jong 1975).

Both irrigation and artificial drainage are expensive items that can dramatically affect the costs of a reclamation program. It is stressed in the manual that these items should be clearly warranted before they are implemented. Full discussions are included that describe a variety of irrigation and drainage techniques that cover a variety of situations and

FIGURE 1: SPILL SITE ASSESSMENT FORM

SPILL SITE ASSESSMENT FORM

DATE: d/m/y _____
LEGAL DESCRIPTION: _____
PREPARED BY: _____

SPILL ASSESSMENT

DATE OF SPILL: _____ (d/m/y) TYPE OF SPILL: brine, oil, emulsion _____

AMOUNT OF SPILL: _____ (cubic meters / barrels) or LENGTH: ____ WIDTH: ____ DEPTH: ____ (meters / feet)

AMOUNT RECOVERED: _____ (cubic meters / barrels) SOURCE OF SPILL: truck, pipeline, tank, etc. _____

PREVIOUS SPILLS: ____ Y/N DETAILS: _____

SOIL CONDITIONS BEFORE SPILL: wet, moist, dry _____

SOIL CONDITIONS AT TREATMENT: wet, moist, dry _____ DATE OF TREATMENT: _____ (d/m/y)

LAND USE: cultivated, pasture, hay, bush, slough, etc. (drawing detail) _____

VEGETATION TYPE PRESENT: _____ EFFECT: kill, discolor, none _____

SITE ASSESSMENT

SOIL TEXTURE: sandy loam, loam, silt loam, clay loam _____ SAMPLES: 0-15, 15-30, 30-60 cm.

SOIL STRUCTURE: dispersed, normal _____ (note locations on drawing)

SOIL PERMEABILITY: fast, moderate, slow, impermeable _____

SURROUNDING TOPOGRAPHY: flat, undulating, hilly, knob and kettle _____

LOCATION: flat, depression, upland, crest, etc. _____

EROSION: none, sheet, rills, gullies, slumping _____

WATER TABLE: at surface, within 1.5 m of surface, below 1.5 m, unknown _____

VEGETATION: Crop; _____ Forage; _____ Bush; _____ Slough; _____

PHOTOGRAPHS: roll and frame numbers; _____

OTHER COMMENTS: _____

SITE DRAWING

INDICATE: North (N)

Scale; (m/ft) _____

Benchmarks (roads, fences, etc)

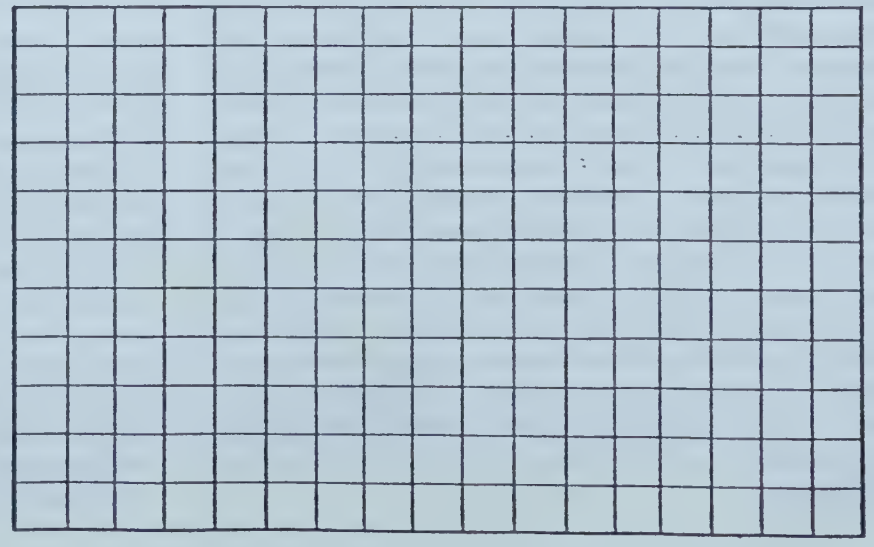
Area of spill

Area of concentration

Slope, drainage, low areas

Sampling locations

Source of spill



prevent costs from rising more than is necessary.

RECLAMATION PROGRAM DESIGN, IMPLEMENTATION AND MONITORING

Proper design of a brine spill reclamation program is critical to the reclamation sucess of a site. A poorly designed program can actually create environmental problems as well as waste a considerable amount of time and money.

The main features that are discussed in the field manual under program design include:

1. Determining calcium requirements.
2. Nutrient and organic requirements.
3. Revegetation, species selection.
4. Physical amendments.

Calcium amendments are the cornerstone of a brine spill reclamation. Calcium displaces sodium from the soil ion exchange complex, reverses soil dispersion and returns soil structure and permeability. There are a variety of calcium-containing products from which to choose and success or failure may depend on picking the right one. For fresh spills, calcium nitrate is the best choice because its high solubility ensures maximum availability of calcium to the soil ion exchange complex and the nitrogen provides an immediate growth stimulus to vegetation. For more established spill sites, where dispersion has occurred, gypsum, ($CaSO_4.2H_2O$) with a fertilizer such as ammonium nitrate (NH_4NO_3), is a better choice. Studies have shown (Warren 1987, Burley 1988) that calcium nitrate does not act any more quickly on a dispersed soil than does gypsum and, since gypsum is a cheaper and more readily available product, it is recommended.

Gypsum tends to lower soil pH and, in acid soils, this is not desirable. For these conditions, a lime ($Ca(OH)_2$) substitution can be made. Sample calculations in the manual are provided that can be used to determine theoretical gypsum requirements in tonnes/hectare based upon soil soluble cation analyses and a conversion factor is also provided for calculating lime requirements from gypsum ones.

Fertilizer (nutrient) and organic amendments are very important, particularly if oil has also been spilled with the saltwater. Oil degradation within the soil requires microbial action which is very nitrogen-intensive. A high nitrogen fertilizer like ammonium nitrate (34-0-0) is required for this situation. An organic amendment, such as manure, not only provides nutrients for plant growth but it maintains the soil surface tilth and friability until the calcium has had enough time to displace the sodium from the soil. A third function it can provide in drier climates is to act as a semi impermeable layer at the soil surface that reduces moisture evaporation. In southern Alberta and Saskatchewan, soil moisture can concentrate salts at the soil surface by transporting them from below via capillary action. The moisture then evaporates and the salts are left behind.

Example fertilizer mixtures are provided and a recommendation to discuss the choice of fertilizer with an expert from the fertilizer industry is suggested.

Revegetation and species selection is important for establishing an initial vegetation cover. Establishment of plant growth on a spill site reduces the surface moisture evaporation and acts as a snow catch in the winter and some halophytic plants actually uptake

salt and remove it from the soil. A table is provided in the manual which recommends different species mixtures for different soil and climate conditions that are found in Alberta and Saskatchewan.

Reclamation and seeding operations should be conducted in the late summer or early fall, after harvest, while access is optimal and reclamation activities will have a minimal impact on farming.

Physical reclamation amendments include artificial drainage, irrigation, sub-soiling and rototilling. Adequate drainage can not be overstressed. Without it, reclamation of a spill site is impossible. Unfortunately drainage installation can be extremely expensive. A variety of techniques are mentioned in the manual which can be used to minimize costs. Examples include weeping the systems, mole drains and trenches. Another potentially expensive physical amendment is irrigation. An adequate supply of water must flow down through the soil profile to leach salt out of the root zone. In drier climates, irrigation is the only means of providing enough leach water. A number of techniques are discussed in the manual that are effective under certain conditions and help minimize costs in those situations. It is emphasized that, in some instances, the high costs must be born if reclamation is to be successful. Rototilling and sub-soiling are means for breaking up soil hardpanning resulting from dispersion. Both these techniques further serve to incorporate amendments into the soil. Correct procedures are given in the manual on how to carry out effective sub-soiling and rototilling.

Program implementation and equipment suitability are discussed in separate sections within the manual but they are essentially different aspects of the same issue. These sections provide the field operator with a knowledge of how to follow the designed reclamation program. Typical equipment for each task is recommended. A variety of sub-soiling, drainage and irrigation techniques are reviewed for different site conditions.

All sites must be monitored for a number of years to ensure success of the reclamation program. Soil and vegetation sampling should be conducted every year. Soil should be analysed for the same items that were originally tested so that a complete set of data in chronological order can be examined for improvements and problems. If deficiencies are evident, then repeat applications of the deficient amendment is warranted. Vegetation data in the form of growth heights, yield and possibly stem-counts will indicate how the reclamation program is performing and highlight whether all aspects have been adequately considered. Monitoring of ground water depth and salt content is useful in determining the extent of groundwater contamination and if the possibility of off-site transfer of salts is likely.

CONCLUSION

A field manual was developed to provide oil field operators a guide for reclamation of mineral (agricultural) soils. The manual serves many purposes:

1. Provides transfer of reclamation research technology to operations personnel.
2. Provides a training manual for new people.
3. Provides an action plan for cleaning up new spills.
4. Provides an action plan for treating new spills.

5. Provides an action plan for treating old/established spills.
6. Develops consistent approach to spill reclamation throughout operations districts.

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AKNOWLEDGEMENTS

The authors would like to thank the following people and organizations for their invaluable assistance in preparing this manual:

H. Heffler
Tera Environmental Consultants
G. Lorenz
Husky Husly Oil Operations-Loydminster, Alta.

PROCESSUS DE REVALORISATION D'UN SITE DEGRADE

PROCEDURE FOR CONTAMINATED SITE RECLAMATION

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Résumé:

Orientation des politiques gouvernementales depuis la cération de la Loi sur la qualité de l'Environnement.

L'étude préliminaire a permis d'orienter toute l'étude et de minimiser les coûts d'opération, tandis gue l'étude exhaustive même a permis de déterminer la nature et la dispersion des contaminants;faire l'estimation des volumes; et, d'établir des mesures de restauration: application des modes de gestion sélectionnés (déchets dangereux, sols contaminés, dépôts secs, eaux souterraines); surveillance environnementale; campagne de rééchantillonnage et suivi.

L'étude du site industriel Stelco Notre-Dame Works touche à la problématique, les types d'investigation réalisés et les modes de gestion appliqués. O y examine aussi la surveillance environnementale et la campagne de rééchantillonnage (volumes de déchets dangereux, sols contamins traités).

La méthode d'évaluation de la contamination et la réévaluation des critères ainsi que les nouvelles technologies en voie de développement offrent des perspectives d'avenir.

Abstract:

Political orientation on the part of the government persuant to the creation of the Law for the quality of the environment.

Characterization study consists of two parts. The preliminary part involves the preparation of the intensive study, while at the same time controlling costs. The intensive part involves determining the nature and the extent of contaminants, volume estimates, and outlining adequate reclamation measures.

Reclamation work involves the application of different managament systems, depending on type of waste. (dangerous wastes, contaminated soils, dry wastes or underground water. Environmental surveillance, resampling & environmental monitoring then follow.

A case study, Stelco Notre-Dame Works industrial site, illustrates the problems, types of investigations carried out, types of management used, environmental surveillance resampling, dangerous waste volumes and treated contaminated soils.

Future outlook involves the contamination evaluation methods/criteria, reevaluation, and new technologies in development stage.

INTRODUCTION

Au moment où l'ampleur des dommages causés à l'environnement par nos rejets industriels, agricoles et domestiques devenait évidente, une nouvelle prise de conscience environnementale prenait naissance au sein de notre société moderne.

Un pas important fut réaliés par les autorités gouvernementales dans le but de rétablir un meilleur équilibre, par la mise sur pied en 1972 au Québec, de la Loi sur la qualité de l'environnement. Cette loi, qui mena à la création du ministère de l'Environnement du Québec en 1978, était le point de départ d'un long processus visant à établir des lignes directrices adaptées dans tous les domaines de l'environnement. Depuis cette époque, le ministère de l'Environnement a défini plusieurs règlements et critères indicatifs spécifiques à divers secteurs problématiques des trois domaines vitaux que sont l'air, l'eau et le

sol. C'est dans cette optique que le ministère de l'Environnement du Québec créa en 1983, le GERLED (Groupe d'étude et de restauration des lieux d'élimination des déchets dangereux), aujourd'hui connu sous l'appellation Division de la gestion des lieux contaminés. Intégré à la direction des substances dangereuses, le GERLED a pu réaliser au cours de son mandat, l'inventaire de 322 sites problématiques ayant reçu différents types de déchets originant d'activités industrielles et minières.

Au même titre que ces sites problématiques, les terrains laissés vacants par le processus de réaménagement de complexes industriels vétustes, en zones résidentielles et récréatives, peuvent représenter des sites potentiellement contaminés. En effet, au cours de leurs années d'opération, ces complexes industriels ont souvent généré la dispersion de substances toxiques dans le sol et l'eau souterraine.

Avant de changer la vocation d'un tel site, il est important de procéder à une analyse approfondie du type et de l'étendue de la contamination de même que de son degré de toxicité. Pour y parvenir, le document publié par le ministère de l'Environnement du Québec en février dernier "Politique de réhabilitation des terrains contaminés" représente un outil de travail essentiel. On y retrouve une grille de critères indicatifs de la contamination des sols et de l'eau souterraine, revue et corrigée, applicable dans le cadre d'une politique globale de gestion, le tout conduisant à la sélection d'un bon mode de restauration.

Ce dont je voudrais traiter aujourd'hui est le processus de revalorisation d'un site dégradé par l'application d'une méthode de travail des consultants tenant compte de la politique mise de l'avant par les autorités gouvernementales et des normes et règlements régissant, en partie, ces travaux.

Qu'il s'agisse d'un lieu d'enfouissement de déchets domestiques ou industriels, d'un site industriel en voie de réaménagement ou d'un terrain contaminé par un déversement accidentel, le processus de revalorisation d'un site dégradé s'établit à partir de certaines lignes directrices. Les étapes de réalisation, même si chaque site doit être considéré comme un cas unique, sont généralement définies de la façon suivante:

DIAGNOSE D'UN SITE POTENTIELLEMENT CONTAMINE

Etude de caractérisation préliminaire:

Le succès de cette première étape permettra d'orienter efficacement l'étude de caractérisation exhaustive et ainsi, garantir le bien-fondé des conclusions et recommandations finales.

La caractérisation préliminaire d'un site potentiellement contaminé représente la compilation de toutes les informations disponibles et pertinentes concernant le site à l'étude de même que les secteurs avoisinants:

- Historique des lieux;
  - Type d'activités;
  - Bâtiments et autres installations;
  - Matières premières utilisées et déchets produits;
  - Déversements et fuites accidentels;
- Cartes et photographies aériennes de diverses époques;
- Donnés géologiques et hydrogéologiques locales et régionales;

- Inspection visuelle sur le terrain et enquête auprès des personnes ressources.

La synthèse de toutes ces informations permet généralement de dresser une liste des contaminants ayant pu être dispersés dans le sol et l'eau souterraine et d'évaluer l'étendue horizontale de la contamination.

Une campagne d'échantillonnage préliminaire, planifiée en fonction de ces données de base, viendra confirmer l'absence de contamination où la présence de contaminants, qui seront par la suite considérés comme paramètres déterminants. Cette première étape vient donc infirmer ou confirmer la nécessité d'une intervention plus approfondie.

Etude de caractérisation exhaustive:

La réalisation de l'étude de caractérisation exhaustive doit mener à l'élaboration d'un portrait précis de l'état des lieux:

- Type de contaminants présents, étundue et gravité de la contamination;
- Dangers pour la santé et la sécurité publique reliés à la présence de la contamination;
- Modes de restauration applicables afin de minimiser ou d'éliminer ces dangers.

Globalement, la définition de ces composantes découle d'un schéma décisionnel qui peut se résumer de la façon suivante: (Tableau Synthèse).

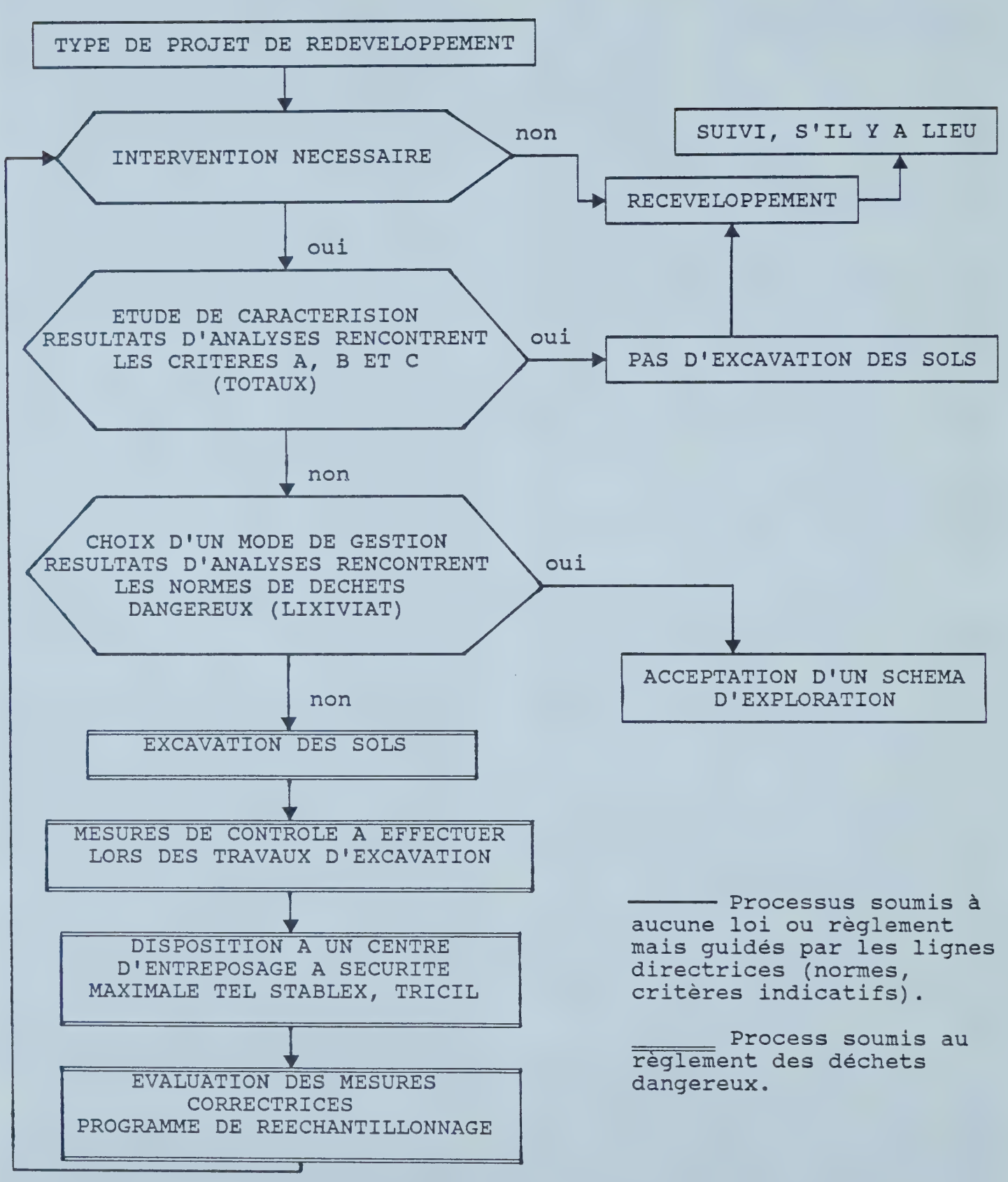
C'est donc l'étude de caractérisation préliminaire qui vient justifier la nécessité d'une intervention. Le cas échéant, la confrontation des résultats de l'étude exhaustive aux critères indicatifs de la contamination suggérés par le ministère de l'Environnement du Québec permettra de caractériser le site à l'étude. Ces critères indicatifs sont un outil de gestion en continuelle évolution, permettant d'évaluer le niveau de contamination d'un site dégradé. Trois seuils de contamination (A, B et C) y sont listés, déterminant trois paliers d'intervention.

On retrouve à l'intérieur d'une grille d'évaluation, une série de critères applicables à une centaine de paramètres déterminants regroupés en dix grandes familles de contaminants potentiels. Pour chacun d'entre eux, une valeur correspondante aux seuils A, B et C a été établie pour la contamination du sol et de l'eau souterraine. Ces critères ont été élaborés par le ministère de l'Environnement du Québec à titre indicatif, et ne doivent pas être considérés comme des normes.

C'est le type d'utilisation envisagé du site qui détermine le seuil de décontamination à atteindre. Ainsi, les critères du seuil C seront généralement utilisés dans le cas d'un développement industriel ou commercial, de la mise en place de rues, de stationnements, de parcs, etc., alors qu'en zones résidentielles ou agricoles, les critères employés devront être beaucoup plus sévères (seuils A ou B). Le mode de restauration final sera donc fonction des usages proposés.

Enfin, il faut souligner l'aspect évolutif de la grille d'évaluation de la contamination en fonction de l'acquisition de nouvelles données. Des ajustements sont souvent possibles, dépendant de la particularité de certains cas.

A partir du seuil sélectionné, un certain volume de sols contaminés pourra être évalué en fonction des résultats d'analyses chimiques.



——— Processus soumis à aucune loi ou règlement mais guidés par les lignes directrices (normes, critères indicatifs).

_____ Process soumis au règlement des déchets dangereux.

MODES DE GESTION

Etant donné que la gestion des sols contaminés est régie par des critères indicatifs, et non par un règlement, le choix du mode de gestion applicable dépend à l'heure actuelle du réglement sur les déchets dangereux entré en vigueur en octobre 1985. Tant et aussi longtemps qu'une législation propre aux sols contaminés n'aura été définie, il faudra tenir compte de la notion de "déchets dangereux" dans le processus de revalorisation d'un site dégradé.

Le choix d'un mode de gestion impliquera généralement la mise en oeuvre d'analyses de lixiviat visant à déterminer l'existence de déchets dangereux dans les secteurs les plus problématiques. Cette étape viendra définir la nature exacte des sols (contaminés ou dangereux).

A ce point, les estimations de volume et de coût peuvent être établies, en fonction de l'interprétation des résultats et du choix d'un mode de restauration.

a) Les dépôts secs:

Ce sont les sols non-contaminés et les différents débris (bois, acier, béton, etc.) présents sur un site dégradé qui ne peuvent être utilisés à titre de matériaux de remplissage ou autres.

Les dépôts secs, soumis au Règlement sur les déchets solides (octobre 1985), peuvent être entreposés dans tous les sites d'enfouissement sanitaire accrédités par le ministère de l'Environnement du Québec.

b) Les sols contaminés:

Les sols contaminés doivent être enfouis dans une cellule de type "sécurité accrue". Le propriétaire du site en voie de restauration peut entreprendre la construction d'une telle cellule sur sa propriété ou expédier les sols contaminés qui y sont présents dans un centre d'entreposage à sécurité accrue accrédité par les autorités gouvernementales. Il existe actuellement au Québec un centre d'entreposage de ce type, Enfouibec Inc., localisé à Bécancour, à mi-chemin entre les villes de Québec et de Montréal.

On y retrouve des cellules étanches à "sécurité accrue", utilisées pour l'enfouissement des sols contaminés. Cette méthode d'élimination se situe entre l'enfouissement sanitaire (dépôts secs) et l'enfouissement de type "sécurité maximale" (déchets dangereux).

Ces cellules sont construites dans un sol naturel constitué d'argile de bonne qualité et ne nécessites pas la mise en place de membranes imperméables synthétiques.

Ce type d'enfouissement requiert également un recouvrement adéquat permettant un bon drainage afin de minimiser l'infiltration de l'eau dans les sols enfouis.

c) Les déchets dangereux:

Les déchets dangereux (sols contaminés jugés dangereux) doivent être éliminés dans un centre d'entreposage de type "sécurité maximale" tel Stablex ou Tricil.

Le propriétaire des sols problématiques peut aussi entreprendre la construction d'une cellule de type "sécurité maximale" sur la propriété où ils sont présents.

Ces cellules doivent être hautement sécuritaires et ce, à longue échéance. Leur conception

doit assurer un confinement efficace, minimiser la production de lixiviat et permettre la récupération des substances liquides accumulées au fond du bassin.

La cellule étanche à "sécurité maximale" se distingue de la cellule à "sécurité accrue" par l'addition dans la barrière imperméable de membranes synthétiques et de membranes naturelles (argile).

La membrane synthétique doit être compatible avec le sol problématique et son lixiviat. Son épaisseur et sa résistance doivent garantir l'efficacité de la cellule à long terme. La cellule étanche devra aussi être munie d'un système de détection des fuites, de collecte du lixiviat et de captage et d'évacuation des gaz.

En ce qui a trait à l'eau souterraine, je ne veux pas élaborer sur cet aspect parfois délicat du processus de revalorisation d'un site dégradé. Généralement, l'élimination des sources de contamination, que sont les sols contaminés ou dangereux, permet la restauration de l'eau souterraine. Dans le cas contraire, des études supplémentaires devraient être entreprises afin de localiser la source de contamination et de remédier à la situation.

PROGRAMME DE SURVEILLANCE ENVIRONNEMENTALE

Avant d'entreprendre tout travail de décontamination, le consultant en charge du projet doit soumettre ses conclusions et son programme de restauration et de surveillance environnementale à l'approbation du ministère de l'Environnement du Québec. Cette approbation se traduit par l'émission d'un certificat d'autorisation dont les exigences doivent être respectées au cours des travaux de décontamination.

L'élaboration et l'application d'un programme de surveillance environnementale adéquat permet au consultant d'atteindre trois objectifs primordiaux lors des travaux de restauration d'un site dégradé, soit:

1. déroulement efficace des activités;
2. protection des travailleurs;
3. seuils de décontamination rencontrant les exigences préétablies.

En plus de retirer du terrain les sols problématiques présents sur le site, la firme de consultants en environnement responsable de la surveillance des travaux doit s'assurer que toutes les activités sur le chantier se déroulent dans le respect des normes prescrites par la Commission de la Santé et de la Sécurité du Travail (C.S.S.T.) en plus de garantir que tous les travaux de restauration répondent aux exigences gouvernementales. Pour ce faire, quatre aspects principaux des opérations constituent le programme de surveillance environnementale:

1. arpentage;
2. excavation et transport des sols contaminés;
3. suivi au centre d'entreposage;
4. campagne de rééchantillonnage.

Arpentage:

L'interprétation des résultats permet de délimiter théoriquement les différents secteurs problématiques. Sur le site, les limites de ces secteurs doivent être dûment piquetées et respectées. Les profondeurs d'excavation doivent faire l'objet d'une attention particulière de la part des inspecteurs en place. Elles doivent être vérifiées à d'aide d'appareils de

précision et l'entrepreneur en charge de l'excavation devra reprendre les travaux aux endroits où les élévations théoriques n'auront pas été atteintes.

Excavation et transport des sols contaminés et des déchets dangereux:

Dans la majorité des cas, et ce en raison de l'absence d'alternative efficace et rentable, les sols problématiques (contaminés et dangereux) doivent être retirés du terrain au moyen d'équipement conventionnel (pelle mécanique) et acheminés par camions vers un centre d'entreposage accrédité par le ministère de l'Environnement du Québec. Les camions affectés à ce type de transport doivent obligatoirement être en bon état et munis de boîtes étanches recouvertes d'une toile bien arrimée. L'extérieur des véhicules quittant le site doit également être débarassé de toute trace de contaminants.

Le transport des déchets dangereux étant règlementé, des manifestes de transport sont fournis aux autorités gouvernementales. De plus, le transport et l'entreposage sont sous l'entière responsabilité du propriétaire du centre d'entreposage à sécurité maximale.

Les procédures à suivre dans le cas des sols contaminés doivent être définies par le consultant responsable des opérations, en accord avec le ministère.

Afin d'éviter tout déchargement de matériel contaminé à des endroits non-autorisés, le contrôle des voyages devrait être exécuté au moyen de fiches de transport des sols. La signature des registres par les inspecteurs en devoir à la sortie du site en voie de restauration et à l'arrivée au centre d'entreposage assurera un suivi efficace des opérations. L'heure de départ et d'arrivée des camions ainsi que le kilométrage parcouru sont ainsi notés et tenus en registres transmis au ministère.

Suivi au centre d'entreposage:

Un inspecteur qualifié de la firme de consultant en environnement vérifiera, si les chargements de sols contaminés attendus pour le quart de travail sont bel et bien arrivés au centre d'entreposage.

La compilation des registres de transport des sols contaminés permettra de déceler les anomalies susceptibles de survenir au cours des travaux. Le matériel contaminé doit être déchargé à l'intérieur des limites déterminées par le propriétaire du site, responsable de l'aménagement d'une cellule à sécurité accrue.

Campagne de rééchantillonnage:

Un programme de rééchantillonnage du sol doit être effectué en vue de déterminer si le niveau de décontamination recherché a été atteint.

Les paramètres de contrôle qui seront analysés sur les échantillons de sol sont les paramètres déterminants dont les concentrations relevées au cours de l'étude préliminaire dépassaient le seuil de contamination retenu.

La campagne de rééchantillonnage du sol doit s'effectuer parallèlement aux travaux d'excavation du sol. Des échantillons composites de sol sont prélevés à la profondeur théorique de décontamination selon une grille d'échantillonnage préétablie. L'échantillon composite doit être constitué de prélèvement (minimum de 5 par secteur) faits en divers endroits sur le secteur excavé.

Dans les cas où les résultats d'analyses s'avèreraient supérie-

urs aux valeurs sélectionnées, une couche de sol supplémentaire serait excavée et une deuxième campagne d'échantillonnage serait entreprise de la même façon, jusqu'à l'obtention derésultats satisfaisants.

La mise en oeuvre de ces mesures de contrôle permettra au consultant de garantir une restauration conforme aux exigences prescrites à l'intérieur du certificat d'autorisation.

Perspectives d'avenir:

A l'heure actuelle, les efforts des différents intervenants sont orientés vers deux aspects cruciaux des opérations de restauration des sites dégradés, soit la réévaluation des critères d'évaluation de la contamination en fonction de l'apport de nouvelles connaissances et le développement de nouvelles technologies de décontamination efficaces et économiquement applicables.

Comme je l'ai mentionné précédemment, la grille d'évaluation suggérée par le ministère de l'Environnement est en constant ajustement. Des recherches sont actuellement en cours afin de déterminer la teneur effective de certains paramètres déterminants dans différents milieu (industriel, commercial, urbain, agricole, etc.). Le but de cet exercice est d'en arriver à des prises de décision les plus réalistes possibles quant aux exigences environnementales à respecter.

Ainsi, le degré de toxicité des contaminants et les dangers réels qu'ils représentent pour la santé et la sécurité publique sont des aspects qui restent à définir plus précisément.

Au fil des ans, les critères d'évaluation de la contamination des sols et des eaux souterraines seront appelés à être modifiés afin de vraiment donner l'heure juste sur la nécessité des interventions devant être mises de l'avant.

Finalement, if faut espérer que dans un avenir rapproché, les consultants pourront bénéficier des nouvelles technologies en voie de développement dans le choix d'un mode de gestion adapté.

Il existe actuellement à l'échelle mondiale divers types de procédés et d'unités mobiles de traitement des sols dégradés. Cependant, les coûts associés à leur mise en application sont encore trop élevés pour la plupart des promoteurs aux prises avec la restauration d'un site dégradé.

Par conséquent, l'enfouissement des sols problématiques dans des cellules étanches constitue à l'heure actuelle la solution la plus valable, tant du point de vue environnemental qu'économique.

BIOLOGICAL POLISHING: THE CHARA PROCESS

POLISSAGE BIOLOGIQUE: LE PROCESSUS CHARA

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Abstract:

The growth dynamics of Chara populations have been under investigation as this aspect is an integral component of the development of a Biological Polishing process using the perennial macrophytic algae. The process is intended to reduce conventional treatment costs of alkaline effluents from mining operations and assist in the fulfillment of environmental effluent guidelines for base metal mining operations.

Dense underwater meadows of Chara in polishing ponds can filter suspended solids, ad/absorb dissolved metals and complex compounds, maintain reducing conditions in sludge ponds, and provide a pH buffering capacity to waste waters (Brierly & Brierly, 1981). Although the algae proliferates in waste water, exhibits tolerance to milling reagents and scavenges metals, the effectiveness of populations of this algae as polishing systems is dependent on those factors determining the sustained perennial standing biomass.

This work's objective was the isolation of the factor(s) controlling the growth of Chara through investigation of four Chara populations in the Timmins area. These populations, though naturally colonizing inactive tailings deposits, were widely variant in their standing biomass [SB: 200 to 2500g (dry weight) per m^2].

The results indicated that SB was not related to the maximum possible age of the populations, while ecotype transplant experiments did not indicate genotypic differences between populations. Chara was the sole macrophyte colonizing these sites, and while filamentous and microalgae populations seldom achieved significant densities, competition was ruled out as the origin of differences in SB between populations. Concentrations of metals in the water remained low (usually <1mg/l) over the duration of the study, while TDS and pH, although variable, could not be related to the SB. Although SB of peripheral populations colonizing the shores of the tailings areas was related to the shallow water depth and physical site exposure, the SB in the central regions was not dependent on water depth, demonstrated by the wide range at similar depths between sites.

Results indicated that the nutrient supply available from the solution and/or sediment is a primary factor controlling population density and growth. However, strictly in terms of concentrations, those nutrients examined, most likely accumulated by Chara from solution, could not be related to SB; rather, the populations' SB appears to be dependent on the total potential nutrient supply, which in turn is dependent on both the concentration of nutrients and total volume of solution in the system. For example, although one population's SB was low, the total content of several essential nutrients was several times that available in solution.

Résumé:

La dynamique de croissance des populations de Chara a été étudiée car cet aspect fait partie intégrante du développement du processus de polissage biologique utilisant les algues macrophytes vivaces. Le processus est utilisé dans l'intention de réduire les coûts de traitement conventionnel des effluents alcalins des opérations minières et aider à l'accomplissement des lignes de conduites environnementales pour les effluents d'opérations minières.

Des colonies denses de Chara à l'intérieur de bassins de polissage peuvent filtrer des solides en suspension, adsorber et absorber des métaux dissous et des composés complexes, maintenir les conditions réductrices dans les bassins de sédimentation, et pourvoir les eaux usées d'une capacité acidifiante pour le polissage (Brierly & Brierly, 1981). Quoique l'algue prolifère dans les eaux usées et démontre de la tolérance face aux réactifs et métaux résiduels, l'efficacité des populations de cette algue comme systèmes de polissage est dépendante de ces facteurs déterminant le maintien d'une quantité de biomasse permanente.

L'objectif de ce travail était d'isoler le ou les facteur(s) contrôlant la croissance de Chara par

l'étude de quatre populations dans la région de Timmins. Ces populations, quoique colonisant naturellement les haldes, étaient très différentes par rapport au niveau de biomasse (200 à 2500g/m2, poids sec).

Les résultats indiquaient que le niveau de biomasse n'était pas relié l'âge maximum possible des populations, quoique des expériences de tranplantation d'écotype n'aient pas indiqué de différences génotypiques entre les populations. Comme Chara était le seul macrophyte colonisant ces sites, alors que les populations de microalgues et d'algues filamenteuses atteignent rarement des densités significatives, la compétition a été exclue comme étant à l'origine de la différence de niveau de la biomasse entre les populations. Les concentrations en métaux dans l'eau sont demeurées basses (habituellement <1mg/l) durant la durée de l'étude, alors que le TDS et le pH, bien que variables, ne peuvent être reliés au niveau de biomasse. Quoique le niveau de biomasse des populations périphériques, colonisant les abords des régions de haldes, était relié à la faible profondeur de l'eau et à l'exposition physique du site, le niveau de biomasse dans les régions centrales n'était pas dépendant de la profondeur de l'eau, comme démontré par la large variation pour des profondeurs semblables entre les sites.

Les résultats ont indiqué que la réserve d'éléments nutritifs disponibles de la solution et/ou des sédiments est un facteur principal contrôlant la densité de la population et la croissance. Cependant, seulement en termes de concentrations, ces éléments nutritifs examinés, plutôt accumulés par Chara à partir de la solution, ne pourraient pas être reliés au niveau de biomasse; plutôt, le niveau de biomasse des populations semble être dépendant de la réserve potentielle totale d'éléments nutritifs, laquelle est, en retour, dépendante de la concentration en éléments nutritifs et du volume total de solution dans le système. Par exemple, quoique le niveau de biomasse d'une population était bas, le contenu total de plusieurs éléments nutritifs essentiels était plusieurs fois ce qui est disponible dans la solution.

INTRODUCTION

Charophytes, a group of macorphytic attached algae, have suitable characteristics to serve as polishing agents in alkaline waste streams from mining operations (Kalin and Van Everdingen 1987). The algae have been tested in ten different waste waters from various base metal operations for growth tolerance and over-wintering ability in the laboratory, as well as on the waste sites (Kalin and Smith 1986).

The potential usage of algal biomass as an bioabsorbant for metals from waste waters has been investigated by many authors (Allelix, 1984, Blake and Dubois, 1982 and Briely and Briely, 1981). In general, the effectiveness of algal biomass as a stand-alone in situ treatment system, despite excellent bioadsorbant characteristics of algal material, is limited, as biomass production is frequently exceeded by the quantity of waste water to be handled, particularly in mining operations.

Despite this, extensively growing algal populations could be used as polishing agents in situations where further conventional treatment is difficult to achieve technically or where further treatment is uneconomical. However, their effectiveness in improving waste water quality will depend on the extent of the algal population and its growth form.

Therefore, ecological factors affecting the growth of algal populations are essential criteria for the development of biological polishing agents, such as **Chara** for use in alkaline waste water treatment for mining operations. Growth controlling factors were investigated throughout one growing season in four different **Chara** populations which have naturally colonized abandoned tailings deposits in the Timmins area (Ontario, Canada).

SITE DESCRIPTIONS

Abandoned gold tailings ponds in the Timmins area have been

Table 1: TAILINGS SITE DESCRIPTION SUMMARY

SITE	1	2	3	4
Ore mined	Ni, Cu	Gold	Gold	Gold
Operation	1973-1977	1910-1968	1936-1979	operating
Since shutdown (y)	9.0	23.0	0.7	-
Tons of tailings($x10^6$)	1.1	66.0	1.5	44.0
Basin (ha)	53.0	200.0	71.0	-
Exposed tailings (ha)	24.0	130.0	60.0	-
Submerged tailings (ha)	29.0	70.0	11.0	-
Chara coverage (ha)	7.0	24.0	3.3	-

colonized by species of Characeae. Four tailings areas were suitable for a detailed investigation of Chara populations, as the characteristics of the populations differed extensively. A summary of the type and duration of production, as well as the dimensions of dry, submerged and Chara-populated areas, is given in Table 1.

Site 2 represents the largest tailings pile, comprised of 66 million tons oftailings covering 200ha, originating from over 58 years of production. The tailings discharge at Sites 1 and 3 ceased 7 and 9 years ago, respectively, with similar tonnage over a comparable area. However, a much larger proportion of the area of Site 1 tailings area is submerged. Site 4 is an operating mine where the number of tons and area of impounded tailings is approaching that of Site 2. Although the ponds at Site 4 are not colonized by Chara, extensive populations of algae are found at foot of most tailings dams. Given the large range of time (7 to 23 years) since the tailings discharge has ceased at the various sites, the time at which the algae have colonized the water cannot be determined.

METHODS

Transects: In mid-May, 1986, transects were drawn from the shore line through the population in each pond, and continued, where possible, to the opposite shore line. Each sampling point of the transects was marked using 1 metre stakes in the more shallow regions of the ponds (< 0.5m deep), while in deeper points on the transects, styrofoam floats weighted by stones were used. Floats were only partially successful as extreme wave action dislodged the floats by late June. Stakes were used to re-mark the locations. Water depth was measured at the transect points on each examination over the season.

Chara Description: The Chara populations were examined in detail on May 16, June 25, October 8 and September 7, 1986. Shoots of Chara were examined at each point of the transects in each pond. Differentiation of the portion of Chara which had over-wintered from the prior season from new shoots was attempted. This would permit quantification of the length and number of whorls of new biomass produced during the growing season.

The morphology of the shoot bases of **Chara** was determined at each transect point, and the population growth form recorded. The presence of reproductive structures (oospores) and epiphytes was recorded.

Biomass and Regrowth: Standing biomass was determined throughout the growing season. **Chara** was raked from one to three $0.15m^2$ areas, and the dry weights calculated as grams per square meter (g/m^2). Increases in biomass per unit area indicated biomass production over the season.

In May, a zone of about $1m^2$ of **Chara** was removed and the perimeter staked for examination of regrowth. Although all the vegetative parts of **Chara** were removed, the seed source, oospores, along with parts of vegetative shoots, could not be eliminated completely.

Ecotype Transplants: Three approaches were used: 1) transplant of living biomass from each of the sites to a common site where large biomass production was evident; 2) transplant of biomass out of a large biomass-producing population to sites with less apparent biomass; and, 3) determination of the biomass of undisturbed **Chara** population. These three experiments were implemented in an attempt to differentiate potential ecotypic components from environmental components which determine **Chara** morphology and populations characteristics.

For all transplanted material living plant biomass was inserted into 20 by 50cm wire racks covered with nylon mesh (spaces 1cm in diameter). Three racks of **Chara** from each of the three tailings sites were weighted with stones to the sediment surface. In early October (105 days), racks were recovered and all **Chara** shoots emergent from the rack netting were cut with scissors and rinsed in pond water. The biomass was then oven-dried and weighed to quantify growth.

The growth of undisturbed **Chara** over the same time period was examined using empty racks laid over a region of undisturbed **Chara** adjacent to the clearance plot in late June. After 105 days (early October), emergent shoots which had penetrated the netting were removed and quantified.

RESULTS AND DISCUSSION

Although two species of **Chara**, C. vulgaris and C. globularis, have colonized all sites, C. vulgaris was, by several orders of magnitude, the predominant species. Thus, all investigations were carried out with C. vulgaris.

Several characteristics determine the growth form of a Chara population. Total shoot length is the product of the number and lengths of internodes. The total shoot length, measured at any time during the growth season, depends on the number of internodes produced in the growth season and the length of the shoot remaining from the prior year. If decay of the shoots is significant in the population, then shoot length can be affected by the rate of decay of the internodes close to the sediment.

Density of the population is dependent on the number of shoots surviving from the prior year, the number of new shoots and the number of new plants established from oospores or vegetative algal fractions. It follows that biomass is therefore a result of many forms of growth which can take place in the population. In

TABLE 2: CHARA MORPHOLOGY, COVERAGE AND BIOMASS PRODUCTION

Averaged Site Data		Depth mm	Biomass g/m2	Cover %	Shoot Length mm
1	MEAN	679	238	87	227
	STD DEV	569	115	23	240
	N	9	9	9	6
2	MEAN	918	250	85	133
	STD DEV	112	243	15	30
	N	6	10	11	4
3	MEAN	236	105	28	60
	STD DEV	167	62	10	11
	N	5	6	6	3

Site 1: 1 high biomass (2.4 kg dropped and 8 observations remained)
Site 2: 7 observations
Site 3: 12 observations

Table 2, the weighted averages of Chara biomass, percent cover and water depth are given.

The Chara population colonizing each tailings site was described by the above parameters on each of three examinations on May 16, June 25 and October 8, 1986. Estimates of Chara coverage were made by visual approximation.

Over the growth season, the morphology of shoots at each site remained remarkably distinct. The deeper ponds seem to produce about the same quantities of biomass and a similar average cover, although the shoot length was different. This does suggest that the populations, although very different in morphology, can produce similar quantities of biomass. Biomass per unit area is an important factor in using the algae as a biological polishing agent.

Water depth along the transects varied over the season, as indicated by the standard deviation, particularly at Site 1. A relationship between biomass and water depth was not apparent; however, a trend was indicated when shoot length and water depth were compared. Shoots were generally longer in deeper waters.

The parameters given in Table 2 do not sufficiently differentiate the populations in their growth character, as the data presented was weighted, excluding extreme values, to arrive at representative average values for each site. A detailed description of the growth from of the algae will however, reveal distinct differences between the populations.

Site 1: At the locations of the pond which had been colonized by **Chara**, growth was prolific. A large population was located parallel to the tailings beach. During May, **Chara** was absent in the shallow water adjacent to the beach (0 to 0.2m deep). During

June and September, the water on the beach had receded, leaving a dry beach. By October, this area exhibited short **Chara** plants originating from oospores. The coverage of this population was 30 percent.

Large plants survived the winter, evident from measurements in the spring. Although the water depth at some locations in the transect are similar to those in Sites 2 and 3, shoots reached lengths of 670mm, compared to 170 and 135 at Sites 2 and 3 at similar water depth.

Chara coverage at this site was, in most locations, consistently around 80 to 100 % throughout the growth period, with the exception of the beach. Biomass per m^2 increased at these three points from 92, 242 and 210g/m^2 respectively, to 340, 326 and 2456g/m^2 between May and October 1986.

Site 2: In May, 75 to 100 % of the sediment surface of the central region of the pond was populated with the prior year's and current spring's growth of **Chara** (Table2). Water depth in the central region was 0.65 to 1.1m. A 25m wide band circumscribed the pond was shallow and wave-swept, conditions which would be detrimental to any rooted vegetation. Between the barren perimeter of the pond and the densely populated centre, **Chara** was sparsely distributed.

In the densely covered central region of the pond, the prior year's shoots were 60 to 130mm long, from which new shoots (20 to 40mm long) emerged. In addition, new shoots grew from the base of old plants. After June, new shoots could no longer be differentiated from old shoots. The maximum shoot length obtained in October was only 50 to 77mm. Biomass increase was observed only in some portions of the transect. The maximum biomass obtained was 760g/m^2 in October, 1986.

Estimates of **Chara** coverage of the sediment surface indicated that, although in some locations coverage increased, **Chara** coverage at other transect points did not increase. In the shallow perimeter, a very sparse cover of **Chara**, 1 to 3cm long, had grown from oospores. They had appeared since the May observation and survived the remainder of the growing season. Given their absence in the spring, these plants probably do not survive winter conditions.

The growth of the Chara populations indicate that the maximum length of the plants did not change over the growth season. Growth over the season appeared to be occurring as an initial shoot production in spring from the prior year's plants with a concurrent growth of a shoot from the bases of these plants. This appeared to increase biomass in the pond and **Chara** cover density. Over the summer, the prior year's growth appeared to disintegrate, as the final lengths of the shoots in the fall were less than in the spring.

Site 3: After May, 1986, shoots of **Chara** did not significantly increase in length over the growth season. However, the biomass and percent surface cover per unit area increased at most transect points between sampling times. This corroborates observations of rapid shoot growth to a maximum length in early spring. Shoot elongation is followed by an increase in the number of shoots over the remainder of the growth season. The maximum biomass of 203g/m^2 was recorded in October, 1986 at this site. In general, the growth of the population at this site appears to be a result of the survivors from the previous

TABLE 3: CHARA GROWTH AND REINVASION

Parameter / Site #	Surrounding Popultation Standing Biomass g/m2 (N)	Surrounding Population % cover	Cleared Zone Regrowth Biomass g/m2 (N)	Cleared Zone % Cover	Surrounding Population Overlay Biomass g/m2 (N)
1	326 (1)	100	74(1)	25	418 (3)
2	760 (1)	100	0	0	0 (3)
3	NR	80	NR	20	0 (3)
4	NR	100	NR	100	310 (3)

Note: Growth period 105 days

growing season and new shoots which emerge either from oospores or vegetative portions of the algae. The density of the over-wintering populations is lower than on Site 2.

From the parameters described and the observations summarized about the different populations, it is clear that the conditions existing at Site 1 are most favourable to biomass increases. The populations at Sites 2 and 3 appear to employ different but successful growth forms for survival. However, these populations are stagnant, remaining in the same state year after year. Factors controlling biomass growth in a population may be linked to those which also affect the ability of the population to colonize areas free of algae.

The ability of **Chara** to regrow in denuded sections of the pond was assessed by the removal of all **Chara** biomass in a designated area. Failure of **Chara** to regrow in this cleared region would indicate the importance of sediment characteristics maintained by the **Chara** populations prior to removal. As **Chara** grew in the zone prior to the clearance under identical conditions of light, depth and water/sediment quality, and the presence of "seeding " sources of **Chara** is guaranteed by the area surrounding the clearance zone (oospores and vegetative fragments of the algae), the conditions for regrowth should be ideal. In Table 3, the results of the regrowth and overlay experiments are presented.

All **Chara** was removed from a $4m^2$ area. In addition, empty **Chara** racks were placed over undisturbed **Chara** surrounding the clearance zone. **Chara** biomass regrown in the clearance zone and penetrating the empty racks was harvested after a 105 day growth period.

No regrowth of the cleared zones occurred in the Site 2 pond and no growth occurred in the overlay. The overlays at Sites 2 and 3 moved extensively due to wave action, and it is possible that new growth occurred which was destroyed physically.

At Site 3, some regrowth of the cleared zone was noted; however, it was too small to quantify. This suggests that both of these populations do not have the ability to recolonize and add biomass to the population in the same fashion as exhibited by Site 4 and Site 1. These populations simply maintain growth, as could

be anticipated from the morphological observations of growth for both sites. On the other hand, the dense populations at Sites 1 and 4 showed good regrowth and extensive growth in the overlays. The cleared zone of Site 4 was approximately 1m deep. The standing crop was in the same order of magnitude as the most dense areas of Site 1 with 1000g/m^2. After 4 months, **Chara** had repopulated 100% of the sediment surface of Site 4 clearance zone, representing somewhat less than one quarter of the annual biomass produced (74g/m2 compared to 418g/m2) at the same site. However, only 15% of the cleared zone of Site 1 had been repopulated by **Chara**. The clearance zones of Site 2 remained entirely bare over the same growth period.

The regrowth results seem to suggest that, for those populations with good annual biomass production (Sites 1 and 4), regrowth of denuded areas is considerably assisted by the presence of previous years growth. In summary, the results from the clearance zone and the overlays indicate that the same growth characteristics prevail as described by the morphological observations expressed in the biomass produced. The populations of Sites 2 and 3, which can be considered as "ticking over", also have little ability to recolonize cleared areas.

Distinct morphologies and growth dynamics were observed in each population over the growth season. However, biomass quantification, clearance zone and overlay experiments have not lead to the identification of environmental factors influencing the growth of the populations. Possibly the differences noted in the populations are an expression of ecotypic variation between populations. A transplant experiment, exchanging living biomass between populations and measuring biomass production, would further assist in the search for growth controlling factors.

Maintenance of distinct growth rates and morphologies would indicate ecotypic differences between populations. Alternately, similar morphologies and biomass production of all populations would indicate that environmental components, other than those described in this study, are dictating the form and rate of growth. In Table 4, the results of the ecotype transfer experiment are presented.

TABLE 4: CHARA ECOTYPE TRANSPLANTS

Chara Source	g/m^2(N) 1	2	3	4
1	213(3)	N.D.	N.D.	395(3)
2	N.D.*	0(3)	N.D.	0(3)
3	N.D.	N.D.		116(3)
4	235(2)	398(1)	901(1)	692(3)

Notes: Chara transplanted to the #4 pond was dragged to the shore (Moose?) prior to the 7/9/86 examination. The growth period was therefore less than 73 days. The plants were dry but intact, thus, biomass could be determined. All other growth periods were 105 days.
N.D.*: Transplant not performed.

Chara was collected from the 4 populations (**Chara** source) and transplanted in racks to cleared areas in the 4 populations (location of transplant). Biomass emerging from racks after 105 days was harvested and weighed.

The results quite clearly indicate that growth is generally good in Site 1 and Site 4, poor in Site 3 and non existent in Site 2. The biomass produced at Site 4, originating from the transfer of

Chara from other sites (poor populations of Sites 2 and 3) is remarkable. However, the best growth was produced by the indigenous transplant with 690g/m^2 (Table 4). Unfortunately, the data set is incomplete, due to loss of transferred racks. The results definitely suggest that growth is affected by environmental factors and not related to ecotypes.

CONCLUSIONS

Although the experiments did not lead to a clear identification of factors controlling the growth and biomass production, some physical conditions described during the study appear to be of significance. Populations of **Chara** survive in shallow water with extreme wave action and shifting sediments; however, the annual biomass production is only sufficient to maintain the population. Annual increases of biomass can be expected from populations growing in deeper and protected waterbodies. Thus, for the application of **Chara** as a polishing agent, the depth of the pond and the wave action are important criteria for the design of the biological system. To delineate further criteria affecting the population dynamics, the chemical characteristics of the sediments and water may play an important role.

ACKNOWLEDGEMENTS

This study was supported by DSS contract No 14 SQ 23440-6-9118 under the auspices of the Canada Center for Mineral and Energy Technolgy. We wish to thank Giant Yellowknife Mines Ltd for site access.

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PREDICTING THE EFFECTS OF WEATHERING ON WASTEROCK SOIL PROPERTIES AT THE KITSAULT MINESITE, B.C.

PREDICTION DES EFFETS D'ALTERATION SUR LES PROPRIETES DES RESIDUS ROCHEUX A LA MINE DE KITSAULT, C.B.

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Abstract:

Although in the last period of mining all soil-sized material encountered during mine expansion was conserved, there are insufficient quantities to use it as a substrate for plant growth on wasterock dumps. Therefore, a forest cover - the end land use objective for the site - must be grown on the wasterock material itself. Field trials have shown that, immediately after exposure, the wasterock is a satisfactory growth medium, better in fact than most of the stockpiled natural soil. Field trials do not, however, show the long term performance of the wasterock. Significant changes may occur in the soil properties as a result of weathering as the wasterock become more at equilibrium with ambient conditions. Properties of interest include: the proportion of soil-sized particles, susceptability to erosion (e.g. % silt and % clay) and concentration of metal released. Two approaches were used to predict the changes that will occur. The first was to characterize the changes that occur in natural soils developed on similar materials in environments like the minesite. The second method was an attempt to simulate the effects of weathering in the laboratory. Results of these two approaches will be discussed.

Résumé:

Bien que lors des derniers développements de l'exploitation minière l'on ait conservé la couche de sol, suite à l'expansion de la mine, les quantités de sol s'avèrent insuffisantes pour les utiliser comme substrat pour la croissance des plantes sur les résidus rocheux. De plus, l'utilisation finale du territoire perturbé tend souvent vers la mise en place d'un couvert forestier sur les résidus rocheux eux-mêmes. Les essais sur le terrain ont démontré qu'immédiatement après exposition les résidus rocheux donnent un médium de croissance satisfaisant sinon meilleur que plusieurs des sols naturels mis en réserve. Les essais sur le terrain n'ont cependant pas montré la performance à long terme des résidus rocheux. Des changements significatifs peuvent toucher les propriétés du sol comme résultat de l'altération lorsque les débris rocheux établissent un équilibre avec les conditions ambiantes. Les propriétés intéressantes sont: la proportion des particules du sol, la susceptibilité à l'érosion (% de limon et % d'argile) et la concentration des métaux liberés. Deux méthodes ont été utilisées pour prédire les changements qui arriveraient. La première était de caractériser les changements qui arriveraient pour des sols naturels développés à partir de matériaux similaires dans des environnements semblables aux mines. La seconde méthode était une tentative pour simuler les effets de l'altération en laboratoire. Les résultats de ces deux approches feront l'objet de la présentation.

NOTE: The CLRA Conference committee regrets that a full copy of the paper was not received in time to be included in the proceedings. For more information, we suggest you contact the author at 604-228-5771.

A SURVEY OF SOIL COMPACTION ON OIL AND GAS WELLSITES IN NORTHEASTERN ALBERTA

ETUDE DE COMPACTION DU SOL POUR DES SITES DE PUITS DE PETROLE ET GAZ AU NORD-EST DE L'ALBERTA

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Abstract:

Twenty-five oil and gas wellsites on agricultural land were sampled to evaluate soil compaction on both non-restored and recently-restored wellsites. On-site and adjacent off-site measurements for penetration resistance were taken at 10cm depth increments to 50cm depth on transects across the wellsite. On five recently-restored sites, soil cores were collected and analyzed for bulk density, particle size distribution, organic matter content, moisture content and large pore-size distribution (to 0.1 bar moisture tension). Significant differences between on-site and off-site data were evaluated using t-tests at a 95% confidence level.

Compaction was highly site specific. Non-restored sites generally showed more significant compaction than restored sites. Within both groups there were fewer compacted sites than non-compacted sites. Compaction, when present, was usually restricted to a depth of 10 to 20cm, but did extend to 40 or 50cm on some wellsites.

Attempts to standardize bulk density by modifying the data to account for the effects of organic matter and texture sometimes greatly altered conclusions regarding soil compaction. This indicated that there is a need to accurately quantify the effect of these variables if bulk density is to be used as an indicator of soil compaction.

Résumé:

Vingt-cinq sites de puits de pétrole et de gaz se retrouvant sur des terres agricoles ont été échantillonnés pour évaluer la compaction du sol sur des sites non-restaurés ou restaurés récemment. Des mesures de résistance à la pénétration ont été faites sur le site et à l'extérieur du site suivant un transect traversant ce dernier. Les mesures étaient prises jusqu'à une profondeur de 50cm par des accroissements de 10cm à la fois. Sur cinq sites récemment restaurés, des échantillons de sol ont été collectés et des analyses ont été faites sur la densité volumétrique, la distribution de la grosseur des particules, le contenu en matière organique, le contenu hydrique et la distribution des macro-pores (à 0.1 bar de tension hydrique). Il y a des différences significatives entre les données prises sur le site et celles prises à l'extrieur du site. L'évaluation statistique s'est faite avec les tests de T pour un degré de confiance de 95%.

La compaction est fortement reliée au site. Les sites non-restaurés présentent généralement une compaction significativement plus grande que pour les sites restaurés. A l'intérieur des deux groupes il y avait moins de sites compactés que de sites non-compactés. La compaction, quand elle est pérsente, était habituellement restreinte à une profondeur de 10 à 20cm, mais s'est étendue jusqu'à 40 et 50cm pour certains sites.

Des tentatives pour standardiser la densité volumétrique en modifiant les données pour tenir compte des effets de la matière organique et de la texture ont parfois grandement changé les conclusions sur la compaction du sol. Cela indique qu'il est nécessaire de quantifier avec précision l'effet de ces variables si la densité volumétrique doit être utilisée comme indicateur de la compaction du sol.

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